California High-Speed Rail Authority

RFP No.: HSR 13-57

Request for Proposals for Design-Build Services for Construction Package 2-3

Reference Material, Part C.5 Geologic and Seismic Hazard Report

CALIFORNIA HIGH-SPEED TRAIN

Engineering Report

RECORD SET 15%
DESIGN SUBMISSION

Fresno to Bakersfield

Geologic and Seismic Hazards Report

December 2013

04/02/2014 - RFP No.: HSR13-57

CALIFORNIA
High-Speed Rail Authority

California High-Speed Train Project Engineering

Fresno to Bakersfield
Record Set
15% Design Submission
Geologic and Seismic Hazards Report

04/02/2014 - RFP No.: HSR13-57

Prepared by:

URS/HMM/Arup Joint Venture

December 2013

California High-Speed Train Engineering

Geologic and Seismic Hazard Report
FINAL

Prepared by:

URS/HMM/Arup Joint Venture

December 2013

Portions of this Report, as indicated below, have been prepared under the direction of the following Certified Engineering Geologist.

THIS SEAL APPLIES TO THE FOLLOWING SECCTIONS/CHAPTERS ONLY:

Chapters 1 through 3, 5 through 11, and Appendices A, B, and C.

Thomas William Berry, PG, CEG

December 23, 2013

DATE

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Geologic and Seismic Hazard Report FINAL

Prepared by:

URS/HMM/Arup Joint Venture

December 2013

Portions of this Report, as indicated below, have been prepared under the direction of the following registered Geotechnical Engineer.

THIS SEAL APPLIES TO THE FOLLOWING SECTIONS/CHAPTERS ONLY:

Chapter 4, Seismic Hazards

Anil Dean, P.E, G.E.

December 19,2013
DATE

04/02/2014 - RFP No.: HSR13-57

Table of Contents

04/02/2014 - RFP No.: HSR13-57

Appendices

Tables

Figures

List of Abbreviations and Acronyms

AP	Alquist-Priolo
ASCE	American Society of Civil Engineers
ASL	above sea level
ASTM	American Society for Testing and Materials
Authority	California High-Speed Rail Authority
bgs	below ground surface
Caltrans	California Department of Transportation
CBC	California Building Code
CDMG	California Division of Mines and Geology
CDWR	California Department of Water Resources
CEQA	California Environmental Quality Act
CGS	California Geological Survey
CHSRA	California High-Speed Rail Authority
CHSTP	California High-Speed Train Project
CPT	Cone Penetration Testing
CWA	Clean Water Act
DOGGR	California Division of Oil, Gas, and Geothermal Resources
EFZ	Earthquake Fault Zone
EL	Elevation
EPA	US Environmental Protection Agency
FB	Fresno to Bakersfield
FEMA	Federal Emergency Management Agency
g	Gravity
GI	Ground Investigation
GIS	Geographical Information Systems
GPS	Global Positioning System
HMM	Hatch Mott MacDonald
HST	high-speed train
IBC	International Building Code
InSAR	Interferometric synthetic aperture radar
JV	URS/HMM/Arup Joint Venture
KMHP	Kern County Multi-Hazard Mitigation Plan
LADWP	Los Angeles Department of Water and Power
MBGP	Metropolitan Bakersfield General Plan
MHMP	Multi-Hazard Mitigation Plan
MRZ	Mineral resource zone
MSL	Mean sea level
M_w	Moment magnitude
mya	Million years ago
N/A	Not applicable
NEPA	National Environmental Policy Act
NOA	Naturally occurring asbestos
NRC	US Nuclear Regulatory Commission
NRCS	Natural Resources Conservation Service
P-C	Production-Consumption
PCC	Portland Cement Concrete
PCF	Poso Creek Fault
PGA	Peak ground acceleration
RC	Regional consultant
RWQCB	Regional Water Quality Control Boards
SCEC	Southern California Earthquake Center

SJV	San Joaquin Valley
SMARA	California Surface Mining and Reclamation Act
SPT	Standard penetration test
TM	Technical memorandum
UBC	Uniform Building Code
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VEI	Volcanic Explosivity Index
WGCEP	Working Group on California Earthquake Probabilities
WQHTR	HST FB Water Quality Hydrology Technical Report

Section 1.0

Executive Summary

1.0 Executive Summary

The regional consultant (RC) carried out a geologic and seismic hazards assessment of the Fresno to Bakersfield (FB) Section of the proposed alignment for the California High-Speed Train Project (CHSTP) (see Figure A1 of Appendix A). The team used information from publically available sources such as the US Geological Survey (USGS), California Geological Survey (CGS, formerly known as California Division of Mines and Geology [CDMG]), the California Department of Transportation (Caltrans), and City planning departments to review and analyze the following geologic hazards:

- Ground rupture and shaking.
- Liquefaction and other seismically induced ground deformations.
- Surface water and groundwater.
- Tsunami and seiche.
- Static and seismically induced landslides.
- Karst and abandoned mines.
- Volcanic hazards.
- Erosion and scour.
- Corrosivity.
- Land subsidence.
- Collapsible and expansive soils.
- Flooding and dam inundation.
- Soft, compressible soils.
- Hazardous minerals.

The data available allowed for a qualitative analysis of the geologic and seismic hazards but was rarely refined enough to enable a specific quantitative assessment of the hazards for any particular section of the proposed alignment.

In accordance with Technical Memorandum (TM) 2.9.3, the purpose of this report is to identify and present the range of hazards across the route with the following specific goals:

- Evaluate and summarize the severity of the risks associated with each identified hazard.

- Provide initial mitigation concepts for these hazards to support the 15% planning and design concepts.

- Provide preliminary recommendations for the mitigation of the hazards identified.

- Provide a basis to focus future geotechnical investigations to further quantify and qualify the hazards identified, with the ultimate goal of developing PE4P design–level recommendations for the mitigation of all hazards.

The RC will address the final mitigation of the hazards outlined in this report in subsequent reports through further ground investigations (GIs) and using a risk assessment process. The term *mitigation* as used throughout this document does not refer to the California Environmental Quality Act (CEQA) definition, which has very specific legal connotations. Rather, it refers to a more generic engineering concept implying that the application of engineering design and construction processes will partially or completely remedy a potential hazard.

The preliminary assessment of geologic and seismic hazards along the FB Section of the HST identified in this study suggests that there is a moderate to high risk of the following hazards:

- Ground rupture — Kern County, Pond Poso Creek Fault, and Edison Fault.
- Seismically induced ground deformations — entire alignment.

04/02/2014 - RFP No.: HSR13-57

- Shallow groundwater — Kings and Tulare Counties.
- Soil corrosivity and expansive soils – entire alignment.
- Loose granular soils where historical dune sand underlies the alignment.
- Strong motion ground shaking – Tulare and Kern Counties.
- Seismically induced flooding — between Fresno and Corcoran and Bakersfield.
- Land subsidence — entire alignment.
- Seasonal flooding — Fresno, Kings River Crossing, Corcoran, North of Wasco, Bakersfield.
- Soft compressible soils – historical Tulare Lake footprint.
- Slope instability — river channel slopes.

Section 8 of this report summarizes and qualifies the risk associated with the geologic and seismic hazards identified, while Section 9 provides a preliminary assessment of the mitigation measures. Most of the hazards either are distributed across the valley (such as potentially liquefiable soils) or run perpendicular to the proposed alignment (such as flood plains); therefore, avoidance by rerouting the proposed alignment may not be a viable option. In addition, the nature and location of the available information is such that, other than making general comments on potential mitigation measures, specific mitigation measures will have to be deferred until a site-specific GI has been completed.

Section 2.0

Introduction

2.0 Introduction

2.1 Project Overview

In 1996, the state of California established the California High-Speed Rail Authority (Authority). The Authority is responsible for studying alternatives to construct a rail system that will provide intercity high-speed train (HST) service on over 800 miles of track throughout California. This rail system will connect the major population centers of Sacramento, the San Francisco Bay Area, the Central Valley, Los Angeles, the Inland Empire, Orange County, and San Diego. The Authority is coordinating the project with the Federal Railroad Administration. The CHSTP is envisioned as a state-of-the-art, electrically powered, high-speed, steel-wheel-on-steel-rail technology that will include state-of-the-art safety, signaling, and automated train-control systems.

The statewide CHSTP has been divided into a number of sections for the planning, environmental review, coordination, and implementation of the project. This *Geologic and Seismic Hazards Report* is focused on the section of the CHSTP between Fresno and Bakersfield, specifically between the CHSTP stations in downtown Fresno and downtown Bakersfield. During the initial planning process, the CHSTP alignment alternatives are dynamic and subject to revision.

2.2 Project Description

2.2.1 Fresno to Bakersfield High-Speed Train Section

The proposed FB Section of the HST is approximately 114 miles long and traverses a variety of land uses, including farmland, large cities, and small cities. The FB Section includes viaducts and segments where the HST will be on embankment or in cut. The route of the FB Section passes by or through the rural communities of Bowles, Laton, Armona, and Allensworth and the cities of Fresno, Hanford, Selma, Corcoran, Wasco, Shafter, McFarland, and Bakersfield.

The FB Section extends from north of Stanislaus Street in Fresno to the northernmost limit of the Bakersfield to Palmdale Section of the HST at Oswell Street in Bakersfield.

2.2.2 Alignments

The FB Section, shown in Figure 2.2-1, is a critical link connecting the northern HST sections of Merced to Fresno and the Bay Area to the southern HST sections of Bakersfield to Palmdale and Palmdale to Los Angeles. The FB Section includes HST stations in the cities of Fresno and Bakersfield, with a third potential station in the vicinity of Hanford. The Fresno and Bakersfield stations are this section’s project termini.

The FB Section of the HST is generally divided into the following subsections with alignment prefixes. Table 2.2-1 and Figure 2.2-1 illustrate the subsections and their corresponding alignments.

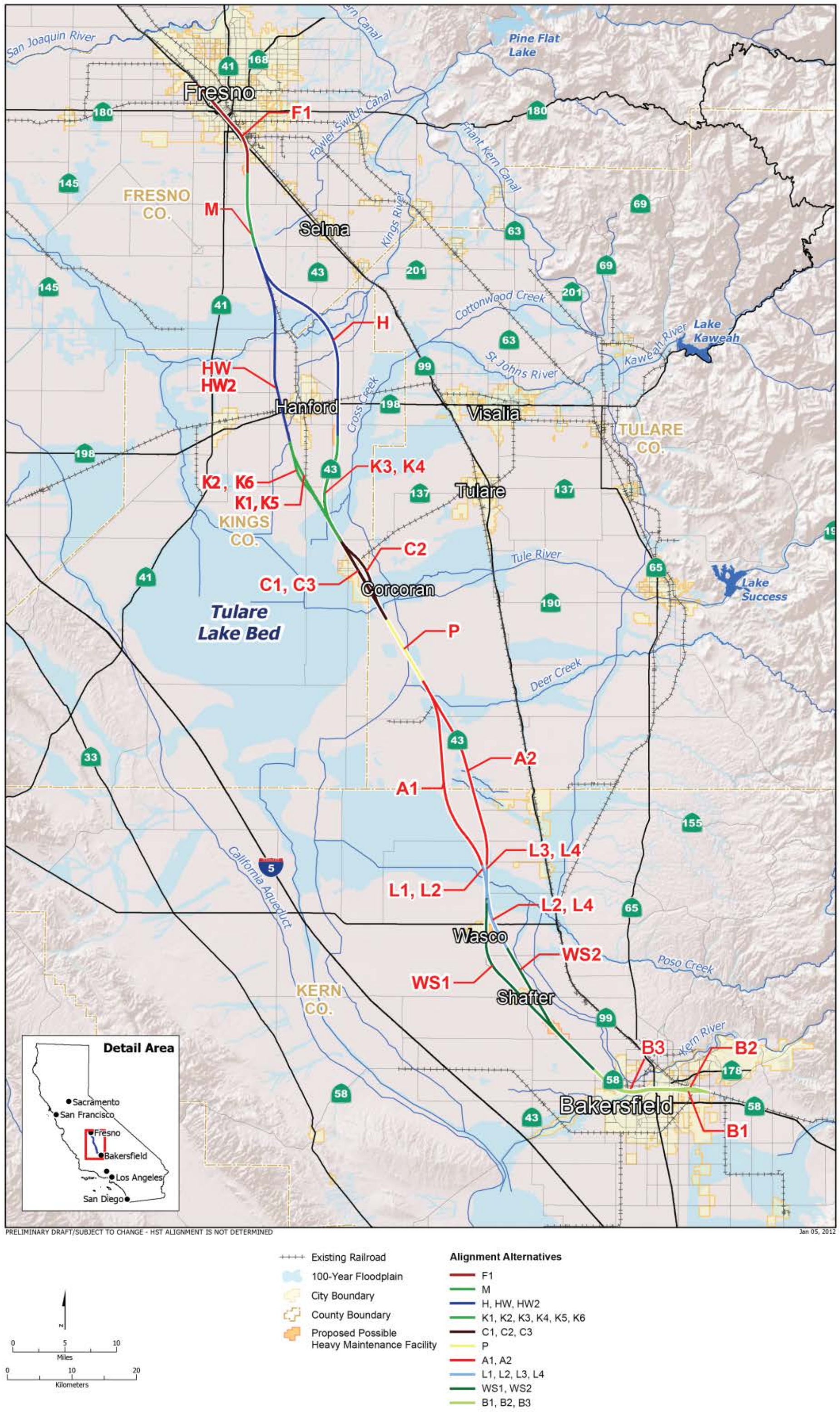

Figure 2.2-1
Overview of Alignments

Table 2.2-1
FB Alignment Subsections

<table>
<tr><th rowspan="2">Alignment Prefix</th><th rowspan="2">Alignment Subsection Name</th><th colspan="2">Location</th><th rowspan="2">County</th><th rowspan="2">Corresponding EIR/EIS Alternative</th></tr>
<tr><th>Begin</th><th>End</th></tr>
<tr><td>F1</td><td>Fresno</td><td>San Joaquin St</td><td>E Lincoln Ave</td><td>Fresno</td><td>BNSF</td></tr>
<tr><td>M</td><td>Monmouth</td><td>E Lincoln Ave</td><td>E Kamm Ave</td><td>Fresno</td><td>BNSF</td></tr>
<tr><td>H</td><td>Hanford</td><td>E Kamm Ave</td><td>Iona Ave</td><td rowspan="3">Fresno and Kings</td><td>BNSF (Hanford East)</td></tr>
<tr><td>HW</td><td>Hanford West Bypass</td><td>E Kamm Ave</td><td>Idaho Ave</td><td>Hanford West Bypass 1 & 2</td></tr>
<tr><td>HW2</td><td>Hanford West Bypass</td><td>E Kamm Ave</td><td>Iona Ave</td><td>Hanford West Bypass 1 & 2 Modified</td></tr>
<tr><td>K1</td><td rowspan="6">Kaweah</td><td>Idaho Ave</td><td>Nevada Ave</td><td rowspan="6">Kings</td><td>Hanford West Bypass 2 (at-grade) (connects to C1 [Corcoran Elevated] or C2 [Corcoran Bypass])</td></tr>
<tr><td>K2</td><td>Idaho Ave</td><td>Nevada Ave</td><td>Hanford West Bypass 1 (at-grade) (connects to C3 [BNSF through Corcoran])</td></tr>
<tr><td>K3</td><td>Iona Ave</td><td>Nevada Ave</td><td>BNSF (Hanford East) (connects to C3 [BNSF through Corcoran])</td></tr>
<tr><td>K4</td><td>Iona Ave</td><td>Nevada Ave</td><td>BNSF (Hanford East) (connects to C1 [Corcoran Elevated] or C2 [Corcoran Bypass])</td></tr>
<tr><td>K5</td><td>Iona Ave</td><td>Nevada Ave</td><td>Hanford West Bypass 2 Modified (below-grade) (connects to C1 [Corcoran Elevated] or C2 [Corcoran Bypass])</td></tr>
<tr><td>K6</td><td>Iona Ave</td><td>Nevada Ave</td><td>Hanford West Bypass 1 Modified (below-grade) (connects to C3 [BNSF through Corcoran])</td></tr>
<tr><td>C1</td><td>Corcoran</td><td>Nevada Ave</td><td>Ave 128</td><td rowspan="3">Kings and Tulare</td><td>Corcoran Elevated</td></tr>
<tr><td>C2</td><td>Corcoran Bypass</td><td>Nevada Ave</td><td>Ave 128</td><td>Corcoran Bypass</td></tr>
<tr><td>C3</td><td>Corcoran</td><td>Nevada Ave</td><td>Ave 128</td><td>BNSF (through Corcoran)</td></tr>
<tr><td>P</td><td>Pixley</td><td>Ave 128</td><td>Ave 84</td><td>Tulare</td><td>BNSF</td></tr>
<tr><td>A1</td><td>Allensworth Bypass</td><td>Ave 84</td><td>Elmo Hwy</td><td rowspan="2">Tulare and Kern</td><td>Allensworth Bypass</td></tr>
<tr><td>A2</td><td>Through Allensworth</td><td>Ave 84</td><td>Elmo Hwy</td><td>BNSF (through Allensworth)</td></tr>
</table>

04/02/2014 - RFP No.: HSR13-57

<table>
<tr><th rowspan="2">Alignment Prefix</th><th rowspan="2">Alignment Subsection Name</th><th colspan="2">Location</th><th rowspan="2">County</th><th rowspan="2">Corresponding EIR/EIS Alternative</th></tr>
<tr><th>Begin</th><th>End</th></tr>
<tr><td>L1</td><td rowspan="4">Poso Creek</td><td>Elmo Hwy</td><td>Whisler Rd</td><td rowspan="4">Kern</td><td>Allensworth Bypass (connects to BNSF [through Wasco-Shafter])</td></tr>
<tr><td>L2</td><td>Elmo Hwy</td><td>Poplar Ave</td><td>Allensworth Bypass (connects to Wasco-Shafter Bypass)</td></tr>
<tr><td>L3</td><td>Elmo Hwy</td><td>Whisler Rd</td><td>BNSF (through Allensworth) (connects to BNSF [through Wasco-Shafter])</td></tr>
<tr><td>L4</td><td>Elmo Hwy</td><td>Poplar Ave</td><td>BNSF (through Allensworth) (connects to Wasco-Shafter Bypass)</td></tr>
<tr><td>WS1</td><td>Through Wasco-Shafter</td><td>Whisler Rd</td><td>Hageman Rd</td><td rowspan="2">Kern</td><td>BNSF (through Wasco-Shafter)</td></tr>
<tr><td>WS2</td><td>Wasco-Shafter Bypass</td><td>Poplar Ave</td><td>Hageman Rd</td><td>Wasco-Shafter Bypass</td></tr>
<tr><td>B1</td><td>Bakersfield Urban</td><td>Hageman Rd</td><td>Baker St</td><td rowspan="3">Kern</td><td>BNSF (Bakersfield North)</td></tr>
<tr><td>B2</td><td>Bakersfield Urban</td><td>Hageman Rd</td><td>Baker St</td><td>Bakersfield South</td></tr>
<tr><td>B3</td><td>Bakersfield Urban</td><td>Hageman Rd</td><td>Baker St</td><td>Bakersfield Hybrid</td></tr>
</table>

2.3 Regulatory Setting

The RC assessed hazards related to geology, seismicity, and soils based on criteria contained in the following regulations, plans, and guidelines:

Federal

- Federal Historic Sites Act.
- International Building Code (IBC).
- National Environmental Policy Act (NEPA).
- Clean Water Act (CWA).

State

- Alquist-Priolo (AP) Earthquake Fault Zoning Act.
- California Surface Mining and Reclamation Act (SMARA).
- Seismic Hazards Mapping Act.
- California Building Code (CBC).
- CEQA.
- Porter-Cologne Water Quality Act.

Local

- Kern County Multi-Hazard Mitigation Plan (KMHP).
- Metropolitan Bakersfield General Plan (MBGP).
- Tulare County General Plan Background Report.

2.3.1 Federal Regulations

Federal Historic Sites Act

The key federal law for geologic and topographic features is the Historic Sites Act of 1935. This law establishes a national registry of natural landmarks and protects “outstanding examples of major geological features.”

International Building Code

The International Code Council (ICC) produces the IBC, which encompasses the former Uniform Building Code (UBC), to provide standard specifications for engineering and construction activities, including measures to address geologic and soil concerns (ICC 2009). Specifically, these measures cover issues such as seismic loading (e.g., classifying seismic zones and faults), ground motion, and engineered fill specifications (e.g., compaction and moisture content). The referenced guidelines, while not comprising formal regulatory requirements per se, are widely accepted by regulatory authorities and are routinely included in related standards such as grading codes. The IBC guidelines are regularly updated to reflect current industry standards and practices, including criteria from sources such as the American Society of Civil Engineers (ASCE) and ASTM International (ASTM, formerly known as the American Society for Testing and Materials).

National Environmental Policy Act [42 U.S.C. Section 4321 et seq.]

The National Environment Policy act (NEPA) requires the consideration of potential environmental effects — including potential effects to geology, soils, and geologic resources — in the evaluation of any proposed federal agency action. NEPA also obligates federal agencies to consider the environmental consequences and costs in their projects and programs as part of the planning process. General NEPA procedures are set forth in the Council on Environmental Quality regulations 23 CFR 771.

Clean Water Act [Section 402(p)]

The CWA provides guidance for the restoration and maintenance of the chemical, physical, and biological integrity of the nation’s waters. The applicable sections of the CWA include the following:

- Permit for Fill Material in Waters and Wetlands (reference Biology) [Section 404] — establishes a permit program administered by the United States Army Corps of Engineers (USACE), which regulates the discharge of dredged or fill material into waters of the United States (including wetlands).
- National Pollutant Discharge Elimination System Program [Section 402] — establishes a permitting system for the discharge of any pollutant (except dredge or fill material) into waters of the United States; a National Pollutant Discharge Elimination System permit is required for discharges subject to Section 402 of the CWA.
- Clean Water Quality Certification [Section 401] — requires that an applicant for a federal license or permit allowing activities that would result in a discharge to waters of the United States obtain a state certification that the discharge complies with other provisions of the CWA; the Regional Water Quality Control Boards (RWQCBs) administer the certification program in California.
- Water Quality Impairments [Section 303(d)] — requires each state to provide a list of impaired waters that do not meet state water quality standards as defined by Section 303(d) and to develop total maximum daily loads for impaired water bodies.

2.3.2 State Regulations

Alquist-Priolo Act

The AP Act addresses earthquake faults that have ruptured the ground surface within the last 11,000 years. While there are several faults in close proximity to the corridor and the Poso Creek Fault crosses the alignment No AP-defined faults with known surface rupture have been identified to cross the alignment within the study area.

Surface Mining and Reclamation Act of 1975

SMARA requires the State Geologist to classify land into mineral resource zones (MRZs) according to known or inferred mineral potential. The primary goal of mineral land classification is to ensure that the mineral potential of land is recognized by local government decision makers and is considered before land-use decisions are made that could preclude mining.

Seismic Hazards Mapping Act

The Seismic Hazards Mapping Act of 1990 addresses secondary seismic hazards such as liquefaction and ground shaking. This act allows the lead agency to withhold permits until geologic investigations are conducted and mitigation measures are incorporated into plans. The Seismic Hazards Mapping Act also addresses expansive soils, settlement, and slope stability. The act is relevant to some of the soil conditions present along the corridor.

California Building Codes

The CBC contains the minimum standards for design and construction in California. The Regional Consultants design teams may adopt local standards other than the CBC if those standards are stricter. Some design considerations associated with seismic hazards are needed to address the appropriate building codes for the site. The CBC adopts all the standards associated with seismic engineering detailed in the IBC.

The Greenbook Standard Specifications for Public Works Construction is produced by a joint committee of the Southern California Chapter of the American Public Works Association and the Southern California Districts of the Associated General Contractors of California. Formal adoption of the Greenbook is through the Greenbook Committee of Public Works Standards, Inc. The Greenbook is focused on public works projects and includes (among other criteria) geologic and soil standards related to construction materials and methods (e.g., grading and placement of fill and base materials), utilities, landscaping and irrigation facilities, pipelines, aggregate, and concrete/asphalt pavement (Greenbook Committee 2009).

California Environmental Quality Act

CEQA Guidelines (Section 15126.2[c]) require identification of significant irreversible and irretrievable environmental changes that a proposed project would cause. These changes include uses of nonrenewable resources during construction and operation, changes that may occur as a result of providing long-term access to previously inaccessible areas, and irreversible damages that may result from project-related accidents.

Geology and soils impacts resulting from the implementation of the project could be considered significant if they cause any of the following results:

- Exposure of people or structures to potential substantial adverse effects, including the risk of loss, injury, or death.

- Rupture of a known earthquake fault, as delineated on the most recent AP Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault.
- Seismic-related ground failure, including liquefaction.
- Landslides.
- Substantial soil erosion or the loss of topsoil.
- Location on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or offsite landslides, lateral spreading, subsidence, liquefaction, or collapse.
- Location on expansive soil, as defined in Table 18-1-B of the UBC, creating substantial risk to life or property.
- Existence of soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater.

Porter-Cologne Water Quality Act [California Water Code Section 13000 et seq.]

This act requires projects that discharge or propose to discharge wastes that could affect the quality of the state's water to file a Report of Waste Discharge with the appropriate RWQCB.

2.3.3 Local Regulations

Multi-Hazard Mitigation Plans

The Fresno County MHMP, Kings County Multi-Jurisdictional MHMP, and the Tulare County General Plan contain goals to protect residents from known geologic and seismic hazards, and to protect residents from personal injury and property damage resulting from unstable soil. To achieve these goals, new structures must be built in compliance with the AP Act and special precautions are considered for proposed critical structures. These critical structures include hospitals, fire stations, emergency communication centers, private schools, high-occupancy buildings, bridges and freeway overpasses, and dams. In addition, structures within areas of known or suspected unstable soils will be appropriately located, designed, and constructed.

2.4 Report Brief

This report follows TM 2.9.3: Geologic and Seismic Hazard Analysis Guidelines (Rev 2, July 08 2011) as a reference. The TM provides guidance for geologic and seismic hazard evaluations based upon *existing* information and data, and presents a framework for the preparation of this *Geologic and Seismic Hazards Report*.

The TM was written with reference to, and is broadly consistent with, key guidance documents prepared by the California Board of Geologists and Geophysicists and Caltrans recommendations for the preparation of geologic and seismic hazards reports. Thus, this document reflects the current best practice within the industry.

2.5 Sources of Information

The RC reviewed available geotechnical information for the study area. Hazard evaluations for landslides and liquefaction derive primarily from published mapping by the Seismic Hazards Mapping Program from the CGS geologic quadrangle mapping. Assessments for fault rupture hazard and ground shaking hazard derive from fault mapping and catalogs, and interactive maps

primarily from CGS and USGS sources. The ground motion seismic hazard assessment used the CGS, USGS, and Caltrans fault database information. The primary sources derive from CGS and include the following:

- California High-Speed Train Project Geology, Soils, and Geologic Resources Technical Report.
- California High-Speed Train Project Geologic and Seismic Hazards Geographical Information Systems Database.
- Probabilistic Seismic Hazard Assessment, State of California.
- Earthquake Fault Zones Maps.
- Probabilistic Fault Evaluation Reports.
- Seismic Hazards Mapping Ground Motion.
- Kern Council of Governments.

The soils information presented here is derived from the United States Department of Agriculture (USDA) State Soil Geographic data set. Other sources of soil information reviewed include the following soil surveys by the USDA Natural Resources Conservation Service (NRCS) (formerly known as Soil Conservation Service):

- USDA Soil Surveys for Eastern Fresno Area County; Kings County; Tulare County, Western Part; and Kern County, Northwestern Part.
- USDA Soil Survey of Kern County, Northeastern Part, California.
- USDA Soil Survey of Tulare County, Western Part, California.

This report also uses the following general sources of information as references. A full list of references cited is provided in Section 11.0 References.

- HST TMs.
- USGS website.
- CGS, CDWR, and CDMG publications and web-based services.
- Caltrans publications and web-based services.
- Local county web-based services.
- USGS publications, particularly USGS Professional Paper 1501 (Bartow 1991).
- Geological maps, particularly the 1:250,000 Geologic Maps of California, Fresno, and Bakersfield Sheets.

The RC derived additional information from a ground model based on historical bore and cone penetration testing (CPT) logs provided by Caltrans as well as geotechnical reports available at County and City levels. The team reduced and entered the data into the geotechnical ground modeling software, gINT, specifically for this project.

2.6 Definition of Subsections

The RC's geotechnical team divided the FB Section of the HST into 11 subsections based on areas of similar terrain, geology or proposed structure. The subsection boundaries are such that pertinent geologic, seismic, and geotechnical information can be easily retrieved by subsequent project participants. Table 2.6-1 details the start and end locations and the length of each subsection, summarized in Figure A1 of Appendix A. The RC has not identified or selected a single preferred alignment, and there are many areas where the RC is considering more than one alignment option in a subsection.

Table 2.6-1
Fresno to Bakersfield Section Subsection Division

Suffix	Subsection Name	Subsection Start	Subsection End	Approximate Length (mi)
A	Fresno	W Clinton Ave	E Central Ave	8.1
B	Rural North	E Central Ave	E Harlan Ave	17.4
C	Kings River Crossing	E Harlan Ave	Fargo Ave	8.3
D	Hanford Station	Fargo Ave	Hanford Armona Ave	3.0
E	Rural Central	Hanford Armona Ave	Poplar Ave/Ave 144	17.2
F	Tule River Crossing	Popular Ave/Ave 144	Ave 128	2.3
G	Rural South	Ave 128	Phillips Rd	30.3
H	Wasco & Shafter	Phillips Rd	Hageman Rd	19.9
J	Bakersfield North	Hageman Rd	Coffee Rd	3.6
K	Kern River Crossing	Coffee Rd	Oak St	3.0
L	Bakersfield South	Oak St	Oswell St	7.1

2.7 Route Descriptions

2.7.1 Fresno (FB-A)

The Fresno subsection is located in Fresno, is oriented northwest–southeast, and runs from W Clinton Avenue to E Central Avenue, a length of approximately 8.1 miles (see Figure A8a of Appendix A). The Fresno subsection has at-grade, trench, and elevated sections. There is one route option (F1) that runs west of the existing BNSF rail line. This subsection consists mainly of industrial, suburban residential, and commercial land. The route passes through the center of Fresno before bearing due south toward the Rural North subsection.

2.7.2 Rural North (FB-B)

The Rural North subsection is located between Fresno and 9 miles north of Hanford (see Figure A8b of Appendix A). The Rural North subsection runs from approximately E Central Avenue to E Harlan Avenue, a length of approximately 17.4 miles. The Rural North subsection has two route options (H and HW) that bifurcate in the vicinity of Conejo. The eastern alignment option (H) runs predominately on a variable-height embankment, with the exception of the elevated Conejo Viaduct structure that crosses over the BNSF line. The western alignment option (HW) runs exclusively on variable-height embankment. The entire subsection passes through agricultural land with associated structures and infrastructure, with grade separations designed for local vehicular traffic to cross the alignment.

2.7.3 Kings River (FB-C)

The Kings River subsection is located immediately north of Hanford. Both the H and HW alignments cross this subsection (see Figure A8b of Appendix A). The H alignment is oriented northwest–southeast while the HW alignments are oriented north–south about 2,300 feet east of S Clovis Avenue. The subsection runs from E Harlan Avenue to Fargo Avenue, a length of approximately 8.3 miles on the east and 6.1 miles on the west. The Kings River subsection is mostly at-grade with elevated sections at the waterway crossings initiating at about E Harlan Avenue and terminating at about E Dover Avenue, including Cole Slough, Dutch John Cut, Murphy Slough, and Kings River. The height of embankment is variable throughout the

04/02/2014 - RFP No.: HSR13-57

subsection. The entire subsection passes through agricultural land and associated structures and infrastructure with grade separations designed for local vehicular traffic to cross the alignment.

2.7.4 Hanford (FB-D)

The Hanford subsection extends from Fargo Avenue to Hanford Armona Road (see Figure A8b of Appendix A). Both alignments from the previous section enter into the Hanford subsection. The eastern alignment is oriented north–south. This alignment is located approximately 3 miles east of the center of Hanford, runs primarily through agricultural lands and is elevated as it passes over Grangeville Boulevard, the BNSF/Union Pacific rail line, and Highway 198. The western alignments are oriented northwest–southeast passing between Armona and Hanford, and have both elevated and depressed profile options for traversing Highway 198 and the BNSF/Union Pacific rail line. The HW2 alignment is included with discussions of the FB-D subsection and the HW alignment. All three alignments are about 3 miles long. For the purposes of this report, where the HW alignment is discussed in the vicinity of Hanford and Armona, it should be taken to mean both the HW and HW2 alignments.

2.7.5 Rural Central (FB-E)

The Rural Central subsection is located between the southern extent of Hanford and 6 miles south of Corcoran (see Figure A8b of Appendix A). This subsection runs from Hanford Armona Road to Popular Avenue/Avenue 144, a length of approximately 17.2 miles. Both of the alignments that pass to the east and west of Hanford pass through this subsection.

The Rural Central subsection can be split into two parts. The northern part, between Hanford Armona Road and Idaho Avenue, is oriented north–south and has three one routes (C1, C2, and C3) on the paralleling the Highway 43 at an offset of about ½ mile to the east. The western alignment (K1 and K2) is orientated northwest–southeast. Both alignments run on variable-height embankments.

South of Idaho Avenue, the eastern alignment swings west, meeting the western alignment about 1.75 miles north of Nevada Avenue near the reservoirs north of Corcoran where the western alignment terminates. Elevated structures carry the eastern alignment over Cross Creek and one of these alignments to the west side of the BNSF railroad and Highway 43. The western alignment (K1 and K2) bifurcates slightly for a length of about 6 miles south of Idaho Avenue, and these two rejoin just south of Lansing Avenue, trending northwest–southeast but at a slight offset from each other. South of the intersection of the east and west alignments, three route options (C1, C2, and C3) remain under consideration to pass through Corcoran — two through-town options (C1 and C3) and one bypass alternative (C2). C1 has two viaduct sections connected with variable-height embankments. The southern part of alignment C2 has a viaduct section crossing Cross Creek and Poplar Avenue/Avenue 144. The southern part of alignment C3 has two viaduct sections crossing Cross Creek and BNSF, connected with variable-height embankments, some with retaining walls.

2.7.6 Tule River (FB-F)

The Tule River subsection is located between 6 miles and 8 miles south of Corcoran and is oriented northwest–southeast (see Figure A8c of Appendix A). The subsection runs from Popular Avenue/Avenue 144 to Avenue 128, a length of approximately 2.3 miles. The Tule River subsection has three route alternatives. Alternatives C1 and C2 consist of a viaduct section followed by variable-height embankments. Alternative C3 consists of retaining walls and a bridge crossing Tule River, followed by variable-height embankments.

2.7.7 Rural South (FB-G)

The Rural South subsection is located between Avenue 128 south of the Tule River crossing and about 6 miles south of Corcoran (see Figure A8d of Appendix A). The subsection runs from Avenue 128 to Phillips Road, a length of approximately 30.3 miles.

The Rural South subsection can be split into two parts: the northern portion between Avenue 128 and about 1 mile north of Avenue 58. This northern alignment alternative (P) is oriented northwest–southeast. Alignment P follows Highway 43 and runs on variable-height embankments. The southern option is oriented northwest–southeast as well and is divided into two alternatives. Alignment A1 (the western alternative) runs on an elevated viaduct crossing Deer Creek near the Pixley National Wildlife Refuge. Alignment A2 (the eastern alternative) follows Highway 43 and runs on an elevated viaduct in the same vicinity of Deer Creek and the Pixley National Wildlife Refuge. Both A1 and A2 then continue south on variable-height embankments. The A1 and A2 alignments end at the beginning of the Poso Creek viaduct, between Sherwood Avenue and Whistler Road.

South of the A1 and A2 alignments, the RC has developed four alignments (L1, L2, L3, and L4) to connect to alternatives WS1 and WS2. Each of these alignment alternatives has a planned viaduct crossing the Poso Creek Channel, with variable-height embankments running north and south of the creek.

2.7.8 Wasco to Shafter (FB-H)

The Wasco to Shafter subsection is located between Phillips Road (about 2 miles north of the Paso Robles Highway 43) and Hageman Road (see Figure A8d of Appendix A). The subsection runs from Phillips Road to Hageman Road, a length of approximately 29.2 miles. At Poso Creek, north of the Wasco to Shafter subsection, the alignment divides into the two Wasco to Shafter alignments, WS1 and WS2.

WS1 alignment consists of two viaduct sections connected by embankments of variable height. The WS2 alignment consists of variable-height embankments and one viaduct crossing the BNSF rail line.

2.7.9 Bakersfield (FB-J, FB-K, and FB-L)

The Bakersfield subsection has been divided into three segments: FB-J, FB-K, and FB-L. The Bakersfield subsections are located between Hageman Road and Oswell Street, and are oriented west–east. There are three alignment alternatives through Bakersfield, designated B1, B2, and B3 (see Figure A8e of Appendix A).

The B1, B2, and B3 alignments start with variable-height embankments. Near Palm Avenue, the alignments transition to an elevated viaduct section until the end of the subsection. The alignments provide for a station in downtown Bakersfield within subsection FB-L. Subsection FB-K includes a crossing of the Kern River, the Central Valley Canal, the Stine Canal, the East Side Canal, and the Friant-Kern Canal, and intertwines with the proposed Westside Parkway, which is currently under construction.

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Section 3.0

Affected Environments

3.0 Affected Environments

The affected environments are defined as the regional and/or local geomorphic, hydrologic and geologic conditions anticipated to be encountered along the HST alignment.

3.1 Geomorphic Province

California is divided into 11 geomorphic provinces as shown in Figure 3.1-1 (CGS 2002). Each province broadly defines an area of similar morphology and often reflects the underlying geologic conditions. The geomorphic provinces are predominantly linear in plan trending northwest - southeast following the generalized topography of the state. The FB Section is located wholly within the Great Valley geomorphic province.

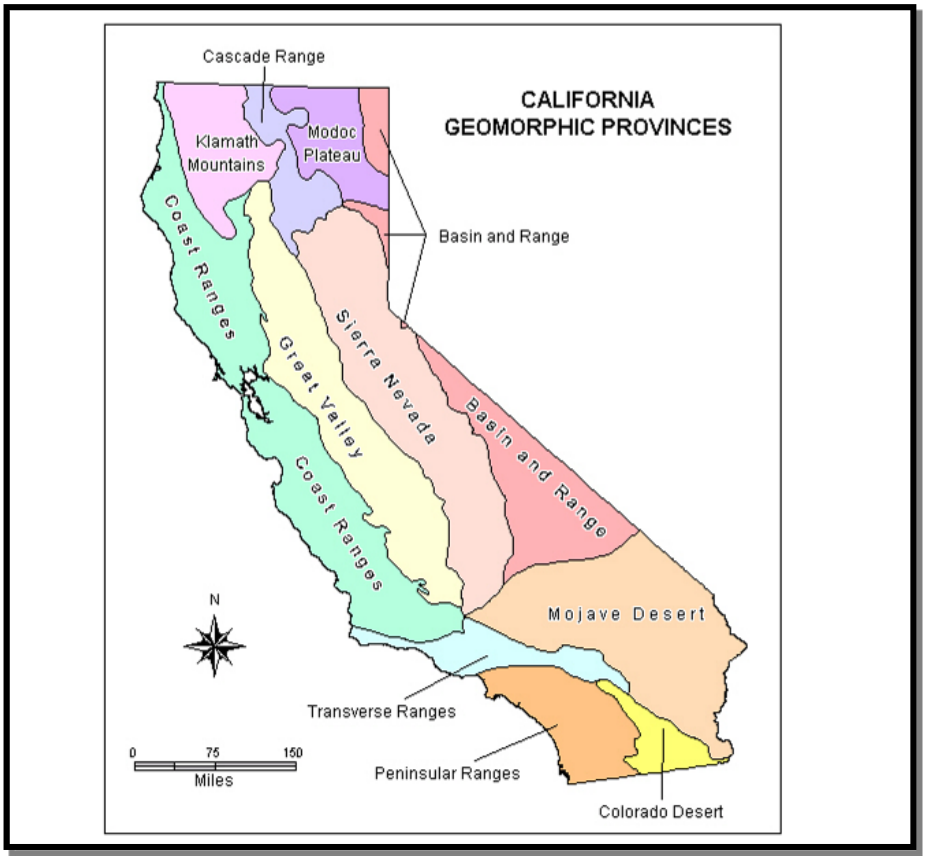

Figure 3.1-1
Geomorphic Provinces of California (CGS 2002)

3.1.1 The Great Valley Province

The Great Valley geomorphic province comprises a large, northwest–southeast trending synclinal trough extending approximately 400 miles in length and about 50 miles in width (CGS 2002). Infilling with sediments has occurred since the Jurassic period (> 145 million years), providing a large, flat-lying alluvial plain setting in which the FB Section corridor will be constructed. Bordering the Great Valley are mountain ranges, principally the Sierra Nevada ranges that represent the Sierra Nevada geomorphic province to the east, and the Temblor and Diablo ranges associated with the Coast Ranges geomorphic province to the west (see Figure 3.1-2).

The Tehachapi Mountains and Klamath Mountains define the southern and northern limits of the Great Valley, respectively.

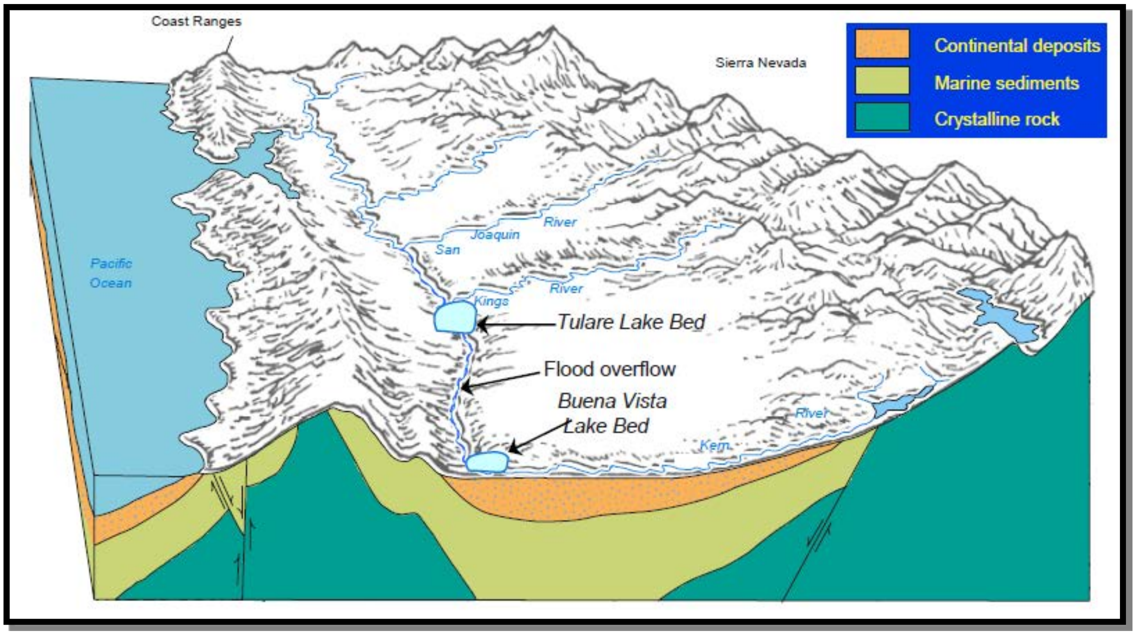

Figure 3.1-2
The Great Valley Geomorphic Province (after Page 1986)

The Great Valley is comprised of two parts: The Sacramento Valley in the north and the larger San Joaquin Valley (SJV) in the south. Specific to this report is the SJV, in which the FB Section corridor is located.

3.2 Geological Setting

The geological map of the entirety of the route section from Fresno to Bakersfield is provided in Figure A2 of Appendix A. The SJV is a large sedimentary basin, but it provides for a somewhat varied geological setting. Given the asymmetry of the synclinal trough with its axis off center to the west (Norris and Webb 1990), basin sediments are deeper on the western side of the SJV compared with the eastern side. Southwestward tilting of the trough has also contributed to greater thickness of sediments at the southern end of the SJV compared with the northern end. Bedrock geology also differs from the east to west:

> To the east of the valley, the Sierra Nevada is composed primarily of pre-Tertiary granitic rocks and is separated from the valley by a foothill belt of Mesozoic and Paleozoic marine rocks and Mesozoic metavolcanic rocks along the northern one-third of the boundary. The Coast Ranges west of the valley have a core of Franciscan assemblage of late Jurassic to late Cretaceous or Paleocene age and Mesozoic ultramafic rocks. (Gronberg et al. 1998)

Such variability is testament to the tectonic environment in which the SJV is located, and the interplay that this tectonic environment has had with the formation of the SJV to the present-day.

Bartow (1991) studied the evolution of the SJV, dividing it into five regions considered to exhibit different stratigraphy and extent of geologic deformation. These regions are shown in Figure 3.2-1, comprising the Northern Sierran Block (NSB), the Southern Sierran Block (SSB), the Northern Diablo Homocline (NDH), the Westside Fold Belt (WFB), and the combined Maricopa-

Tejon sub-basin and south-margin deformed belt (M-TS) regions. The eastern portion of the valley, represented by the NSB and SSB regions lying to the east of the valley axis, is the least deformed compared with the remaining regions, showing less evidence of faulting and folding. Presence of faults and folds are far more evident in the western NDH and WFB regions, adjacent to the San Andreas Fault defining the plate boundary. The M-TS region at the southern end of the SJV represents the most highly deformed region, exhibiting the most basin subsidence and seemingly accommodating the brunt of regional compressional tectonic forces.

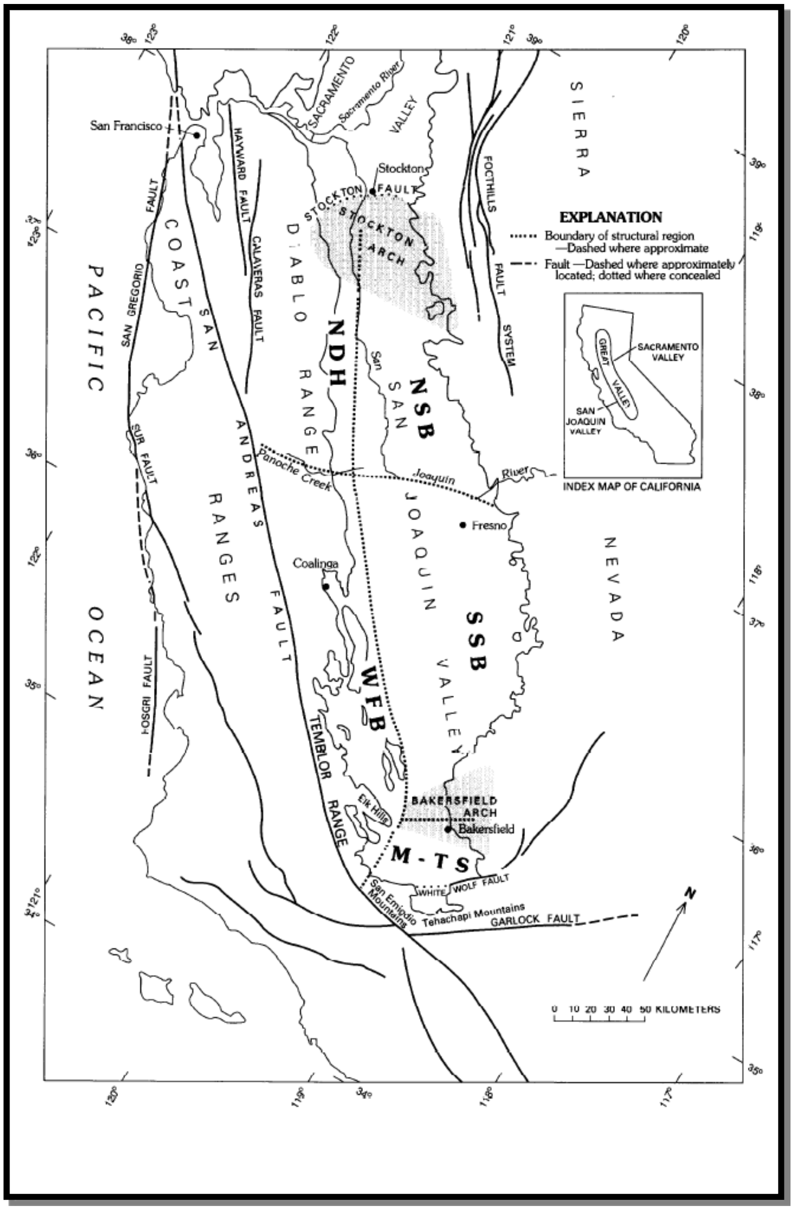

Figure 3.2-1
San Joaquin Valley Geologic Structural Boundaries (Bartow 1991)

The majority of the FB Section corridor traverses the South Sierran Block (SSB) region that represents a relatively stable geological setting. In approaching Bakersfield from the north, the alignment approaches the more deformed Maricopa-Tejon Sub-basin region, located over the buried Bakersfield arch structure that defines the boundary between these regions. A generalized longitudinal section of the SJV extending from the Tule River Crossing to the White Wolf fault is

shown in Figure 3.2-2, serving to illustrate the progressive change in geology from north to south.

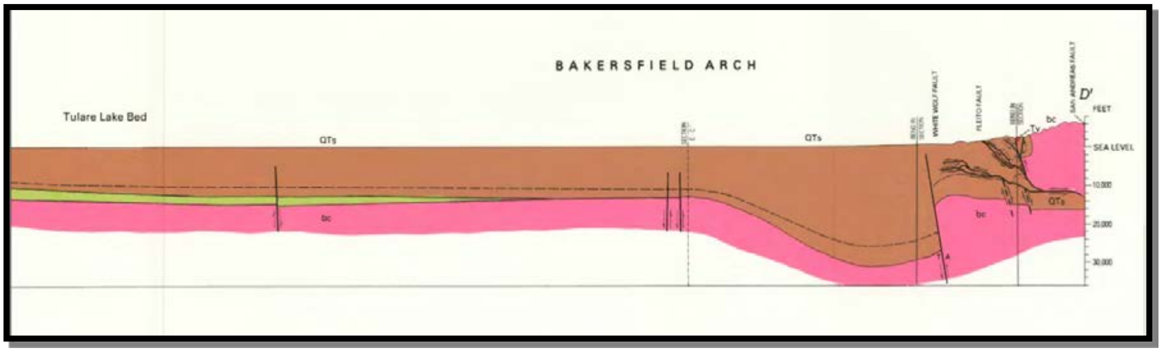

Figure 3.2-2
Geologic Cross Section of Study Area (Bartow 1991)

3.3 Stratigraphy

3.3.1 Basement Geology

The basement rocks of the SJV consist of the Sierran and Coast Range basement rocks. Tilting down to the southwest and extending under the SJV, the Sierran basement rock is comprised of Mesozoic granitic intrusive (igneous) rocks and pre-Jurassic metamorphic rocks (Norris and Webb 1990). Coast Range basement rocks have a core of late Jurassic to late Cretaceous or Paleocene age sedimentary rocks and Mesozoic ultramafic igneous rocks (Bartow 1991; Gronberg et al. 1998).

3.3.2 Jurassic to Neogene (150 million to 2.6 million years ago [mya])

Above the basement rocks of the SJV there is up to approximately 30,000 feet of sedimentary rocks deposited from the Jurassic Period (220mya to 146mya) through the end of the late Miocene Epoch (23mya to 5mya). The sedimentary rocks of the SJV sequence are composed of mudstones, sandstones, and conglomerate representing deep marine sediments to the west of the valley, grading to shallow marine and deltaic sediments to the east. These deposits are representative of a forearc depositional environment with the shoreline of the ancient sea approximately located along the western edge of the current Sierra Nevada Mountains and the subduction zone at about the location of the current Pacific coastline (Bartow 1991).

Subsidence throughout the Mesozoic and late Cenozoic Eras has resulted in accumulation of extensive thicknesses of sedimentary rocks. In the northern part of the SJV during the Miocene Epoch, the rate of uplift or sedimentation exceeded the rate of subsidence, leading to a deposition change from marine to deltaic and terrestrial deposits, coinciding with a period of volcanic activity. Marine sedimentation continued in the southern part of the SJV until late Pliocene Epoch (5.3 to 2.6 mya) (Bartow 1991).

3.3.3 Quaternary (<2.6 mya)

Around 2mya, the SJV emerged above sea level (ASL) and became isolated from the ocean. Much of the valley floor was then occupied by shallow lakes including a large lake known as Lake Corcoran that resulted in widespread deposition of a lacustrine deposit known as Corcoran Clay (Norris and Webb 1990). This unit is a massive, highly diatomaceous, silty clay deposit generally 50-120 feet thick, and generally 150-800 feet beneath the surface, extending over an area

greater than 4,000 square miles (Frink and Kues 1954). The Corcoran Clay deposit thins out at the edges and is thickest in the center of the valley near Corcoran.

Present-day surficial geology comprises largely alluvial deposits and lacustrine deposits, although dune sand, basin, stream-channel, Pleistocene Epoch (2.6 to 0.1 mya) nonmarine and other nonmarine deposits are also mapped (Gronberg et al. 1998). The majority of the alluvial deposition is from east to west where the rivers from the Sierra Nevada deposited alluvial fans extending westward for 40 miles and covering more than 80% of the floor of the SJV. This material is composed of coarse-grained silicate and feldspathic material (silt, sand, and gravel sized fragments) with periodic (possible seasonal but possibly longer) deposition of fine-grained sediment (silt and clay).

3.4 Geologic Features

3.4.1 The Southern Sierran Block

Bartow (1991) defines the SSB region as follows:

> The southern Sierran Block [SSB] comprises the southern part of the stable and little-deformed east limb of the valley [SJV] syncline. Its south boundary is the crest of the Bakersfield arch, a broad southwest-plunging ridge of basement rock, and the north boundary is arbitrarily placed at the San Joaquin River. Both Cenozoic and Mesozoic sedimentary deposits thicken gradually southward and together total more than 5,000 m [16,400 feet] in the area south of Tulare Lake. Cenozoic strata alone [shown in brown on Figure 3.2-2] reach a thickness of more than 4,500 m [14,750 feet], whereas the Mesozoic rocks [shown in green on Figure 3.2-2] thin southeastward and pinch out or are truncated against the north flank of the arch.

Bartow notes that knowledge of the Tertiary-age (65mya to 2.6mya) sediments north of the Bakersfield arch area is lacking. “Outside the arch area, Tertiary rocks, particularly the older Tertiary, are not well known because of the absence of Tertiary outcrops between the San Joaquin River and the Tule River and the sparsity of deep wells” (1991). As the central part of the SSB at this time represented the transition from marine to nonmarine deposition, it is considered that the stratigraphy in the northern part of the SSB would have similarities with both the Bakersfield arch area and neighboring Kettleman Hills area to the west (Bartow 1991).

3.4.2 The Bakersfield Arch

Crossing the SJV near its southern end, the Bakersfield arch is a major buried basement feature that takes the form of an anticlinal structure plunging downwards in a southwesterly direction. The general extent of the structure in plan is shown in Figure 3.4-1, as defined by Bartow (1991). Sheehan (1986) also described its form and location as a ”major westward-plunging structural bowing on the east side of the southern San Joaquin Valley [SJV], extending from Porterville on the north, approximately 55 mi south-southeast to the vicinity of Bear Mountain. It plunges south-southwest into the San Joaquin basin for approximately 16 mi.” Beneath the axis of the arch at its southwest end, depth to basement rock is estimated to be more than 13,000 feet (Sheehan 1986).

Sheehan (1986) proposes that uplift of the Bakersfield arch began as the result of a massive block of the Sierra Nevada Ranges pushed passively into the SJV by the Tehachapi Mountains, initiated by tectonic extension in the neighboring Basin and Range geomorphic province. Saleeby and Saleeby (2008) note that the arch is actively growing and ascribe recent uplift (in the past 2-3 million years) to rise of the underlying asthenosphere on which the earth’s crust moves.

Regardless of its geologic origins, the anticlinal form of the arch has trapped oil deposits and the area defines a concentration of oil fields. The Bakersfield arch is therefore an area of great economic importance with ultimate oil production from this area estimated to be approximately 25% of the entire SJV (Sheehan 1986).

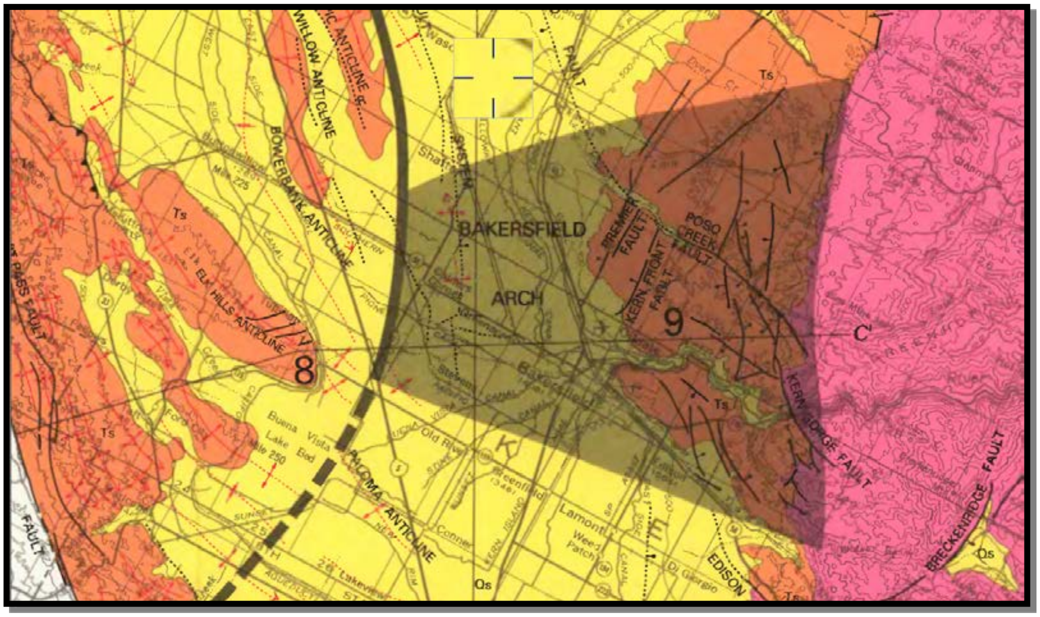

Figure 3.4-1
Structural Limits of the Bakersfield Arch (Bartow 1991)

3.4.3 The Maricopa-Tejon Sub-Basin

The M-TS region, representing the southernmost portion of the SJV, is characterized by deep sediments and thrust faulting. As defined by Bartow (1991), this region consists of two localized structural depressions - the Maricopa sub-basin to the northwest and the Tejon Embayment to the southeast - together with the deformed belt of the north flank of the San Emigdio Mountains. The White Wolf Fault serves to separate the Maricopa sub-basin from the Tejon Embayment. These structural depressions reveal a history of mostly subsidence and concomitant infilling (Samano 2008). The thickness of sediments is the greatest in the Maricopa sub-basin, extending to over 30,000 feet in thickness and representing the deepest sediments in the SJV (Bartow 1991).

Collectively, the M-TS region demarcates the most highly deformed portion of the SJV. Providing a lead role has been regional tectonism, initiated in the Oligocene to early Miocene Epochs (20 mya to 30 mya) by transition from a convergent to transform plate boundary setting as the westward approaching Pacific plate collided with the North American plate. The ensuing tectonic actions have resulted in the faulting and folding now evident, largely the result of regional crustal compression in the north–south direction that persists to the present day (Bartow 1991; Samano 2008). The movement along the White Wolf Fault in 1952 and destructive earthquake that followed is a recent manifestation of the northward thrust imposed on the M-TS region. A cumulative vertical movement of at least 2.2 miles is estimated to have occurred along this fault (Bartow 1991), emphasizing the extent of deformation that has taken place to date.

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3.4.4 Continuing Tectonics

The imprint of tectonics on the SJV is most evident in the M-TS region, but given the geologic setting of the SJV, surrounded by highly deformed rock units subject to tectonic forces, tectonics and associated seismic hazards remain an ongoing consideration. Bartow (1991) pointed to the steeper west flanks of the buried Corcoran Clay deposit, now located between 200 to more than 650 feet below sea level, as recent (in the past 600,000 years) evidence of tectonic subsidence as well as concurrent uplift of the Coastal Range mountains. He also notes the far more recent 1983 Coalinga earthquake that may be representative of more extensive eastward-directed folding and thrusting along the entire west margin of the Great Valley. Hence, seismic hazards along the FB Section corridor are expected to be particularly relevant in the southern portion of the alignment, but also remain a consideration throughout.

3.5 Faulting

The study area is bounded to the west by the seismically active central Coast Ranges. The Coast Ranges are traversed by faults of the San Andreas Fault system, including the San Andreas Fault itself, as well as by several active reverse faults. To the south, the study area is bounded by the Wheeler Ridge and Pleito Thrust faults. To the east and southeast, the study area is bounded by the active White Wolf, Garlock and the Southern Sierra Nevada Faults. Beyond the Garlock and the Southern Sierra Nevada Faults to the east lie two broad zones of distributed shear: the Sierra Nevada Fault Zone (SNFZ) and the Eastern California Shear Zone (ECSZ). These zones accommodate the movement between the Pacific and North American plates, which has resulted in a number of large, damaging earthquakes during historic time.

The Breckenridge and Kern Canyon Faults, extending north of the White Wolf Fault through Isabella Dam, have recently been classified as active or potentially active and, as such, pose a seismic risk to the study area (City of Bakersfield 2002). Closer to Bakersfield, the Caltrans 1996 Seismic Hazard Map (Caltrans 1996) designates the Kern Gorge Fault, the Kern Front Fault, and several faults to the east of Oildale in the Oil Field Fault Zone (North and South) as significant potential seismic sources.

3.5.1 Fault Activity Terms

This section discusses faults crossing or in close proximity to the HST alignment, which are classified first as capable and further classified as either hazardous or potentially hazardous. Classification of these faults is based on the project specific definitions below, as well as other relevant criteria.

Faults along the HST alignment are classified based on project specific criteria and definitions presented in TM 2.10.6 and TM 2.9.3.:

- Capable Fault – A mapped or otherwise known Quaternary fault with evidence of Holocene activity (most recent movements within the past 11,000 years), structural relationship to Holocene fault(s), and/or where data are not sufficient to rule out Holocene movement.
- Potentially Hazardous Fault – A fault having known or documented Holocene activity, or a known Quaternary fault with suspected Holocene activity.
- Hazardous Fault – A potentially hazardous fault that has slip rates or recurrence intervals documented in peer-reviewed reports, with > 1 millimeter/year slip rate (SR) and < 1000 year recurrence interval (RI).

3.5.2 On the Alignment

Along the FB Section, there are no known “capable” or seismically active fault crossings as defined by the AP Earthquake Zoning Act. The mapping of faults, however, is dependent on geological information. The depth of sediments in the Central Valley, in excess of 30,000 feet, has restricted the mapping of the structural geology of the bedrock, and therefore faulting is likely to be under-reported in this area.

There has, however, been ground rupture associated with the Poso Creek Fault (PCF) away from the alignment to the south, that traverses the alignment just south of the Town of Pond and some rupture associated with the 1952 Kern County (Arvin-Tehachapi) earthquake at several unnamed faults in the vicinity of Edison close (1500 feet) to the alignment. Movement on the Pond Fault (located away from the alignment) has also been recorded, however this has been attributed to groundwater withdrawal i.e. not tectonic activity).

Published literature also suggests that the western trace of the Edison fault has also experienced historical movement. However, the fault crosses the HST alignment within the Bakersfield study area, and is included here for information only. Figure A3 of Appendix A shows Quaternary faults as mapped by the USGS along the proposed alignment.

Faulting as a result of subsidence related ground movement has been identified in the Kern County region. Therefore, it is prudent, given the current rate of subsidence in the Bakersfield area, to presume that these could also manifest themselves as surface ruptures and should be accounted for over the design life of the HST.

3.5.3 Adjacent to the Alignment

Active and potentially active faults have been mapped near the proposed alignment by a number of government agencies and scientific entities. The mapping of faults is dependent upon geological information. Numerous published maps and reports have been prepared by the USGS, the CGS, and other state or public agencies (e.g., Caltrans, SCEC) that present information on fault location and activity. Kern County in particular is in one of the more seismically active areas of California, has a documented history of significant and recurrent seismic activity, and may at any time, be subject to moderate-to-severe ground shaking. This potential is because of the presence of many major active faults in portions of the county. Table 3.5-1 presents a list of capable faults within the vicinity of the study area, the fault types, the slip rates, and the approximate shortest distances to the HST alignment. Figures A3 and A4 Appendix Aof Appendix A present a regional fault and epicenter maps, respectively, showing the approximate location of the study area in the regional context of seismic sources.

The following sections describe each fault included in Table 3.5-1.

Table 3.5-1
Capable Faults within the Study Area (Reference see bottom of table)

Fault Name	Fault Type	Slip Rate (mm/yr)	Distance and Bearing to FB Section
San Andreas	Right-Lateral Strike-Slip	20-35	47 miles (or more) W of alignment
Great Valley (Segments 10-14)	Blind Thrust	1.5	25–35 miles (or more) W of alignment
Ortigalita	Right-Lateral Strike-Slip	0.5 to 1.5	64 miles W of Fresno
San Joaquin	Reverse	-	57 miles W of Fresno, slightly E of Ortigalita Fault
O'Neill	Reverse	-	58 miles W of Fresno, slightly E of Ortigalita Fault
Nunez		-	48 miles W of Corcoran
Foothills	Normal	0.1	90 miles NW of Fresno; 40 miles E of Stockton
Round Valley/Hilton Creek	Normal	1	80 miles NE of Fresno
Clovis Fault	-	-	12 miles E of near Clovis
Corcoran Clay Fault Zone	Normal	-	Spanning across the HST alignment from Hanford to the Kern/Tulare County line.
Owens Valley	Right-Lateral Strike-Slip	1.5	85 miles E of alignment
Kern Canyon	Normal	-	66 miles E of alignment at Hanford
Kern Front	Normal	-	30 miles SE of Tule River Crossing
Kern Gorge	Normal	-	14 miles NE of Bakersfield
Southern Sierra Nevada (Independence Section)	Normal	0.1	80 miles W of alignment
Oil Field Fault Zone (North)*	Normal	-	2.25 miles N of alignment
Oil Field Fault Zone (South)*	Normal	-	0.75 miles N of alignment
Garlock	Left-Lateral Strike-Slip	2-10	34 miles SE of alignment
White Wolf	Left-Lateral Reverse	3-8.5	13 miles SE of alignment
Breckenridge	Normal	-	18 miles E of alignment
Poso Creek/Pond	Normal	-	0/2 miles E of alignment
Wheeler/Pleito	Normal	1.4	30 miles S of alignment
Edison Fault	Normal	-	Edison Fault Crossing is in Bakersfield and is discussed in Bakersfield to Palmdale alignment. Listed here for information.
Southern Sierra Nevada (Haiwee Reservoir)	Normal	7-14	44 miles E of alignment

* These faults appear on the Caltrans 1996 Seismic Hazards Map but have apparently have been derated since they do not appear on the Caltrans 2007 Deterministic Peak Ground Acceleration Map.
Source: SCEC 1999, WGCEP 2007, Caltrans 2007, USGS, CGS
Note: Faults located a significant distance from the alignment are not shown on Figure A3 of Appendix A

San Andreas Fault

The City of Bakersfield General Plan provides a description of the San Andreas Fault and its displacement characteristics.

> The San Andreas Fault is approximately 650 miles long reaching from a submarine intersection with the Mendocino escarpment at the north to the Imperial Valley at the south. Along this extent, the San Andreas Fault is considered to be the boundary between the North American Plate and the Pacific Plate. These plates have relative motion such that the Pacific Plate has been moving to the northwest at rates estimated from 1-1/2 to 2-1/2 inches per year (Anderson 1971) for the past 30 million years. Not all of the movement has been accommodated on the San Andreas Fault, but it has slipped the most and is the most conspicuous feature of the plate boundary.
>
> The geologic history of displacements along the San Andreas Fault has only recently begun to yield to investigations. No clear and consistent picture has yet emerged from these investigations. Difficulty arises in attempting correlations of geologic markers across the large offsets present in the fault, and any attempt is complicated by non-uniform offset along the fault (i.e., accommodations of slip by other structures) and by many episodes of movement. In general, the maximum Quaternary offset from a single earthquake cannot be determined because of the superposition of the effects of movements. However, a study by Wallace (1968), which notes the frequency of occurrence of stream offset distances across a portion of the San Andreas Fault, attempts to reconstruct the history of the movement.
>
> The lack of means for dating particular offsets precluded the desired time history and only one peak was evident in the distribution of offset distances. This peak was 30 feet and was attributed to the 1857 earthquake. Wallace concluded that 30 feet may well represent the maximum possible displacement along this portion of the San Andreas Fault. Such a value compares reasonably well with values for the 1906 San Francisco earthquake, 15-1/2 feet average maximum with 21 feet at one locality.
>
> In the 1857 Fort Tejon earthquake, the San Andreas fault was ruptured for a distance of 200 miles or more. This earthquake is known only by a few historical accounts but it is certainly ranked as one of California’s greatest earthquakes and its magnitude has been estimated as 8.0± 0.5 (California Division of Mines 1972). The segment of the San Andreas through Kern County is relatively short compared to its 650 mile length. It is important, however, because the system breaks from its predominant northerly trending direction between the San Luis Obispo and Los Angeles County lines. A significant reason for the break may be the existence of the Big Pine Fault, trending SW into Lockwood Valley and the Garlock Fault, trending NE near Lebec. (City of Bakersfield 2002).

Earthquake frequency on the Southern San Andreas Fault zone varies greatly. At Parkfield, earthquake frequency ranges from under 20 years to more than 300 years elsewhere, (SCEDC c) with the an average recurrence interval for the Mojave segment of 140 years (ibid.). Geologic studies show that over the past 1,400 to 1,500 years large earthquakes have occurred at about 150-year intervals on the southern San Andreas Fault. As the last large earthquake on the southern San Andreas occurred in 1857, that section of the fault is considered a likely location for an earthquake within the next few decades.

The Great Valley Fault System

The Great Valley Fault System (GVFS) represents eastward-directed subsurface folding and thrusting along the west margin of the SJV. According to the Caltrans 1996 Seismic Hazard Map (Caltrans 1996), where the GVFS is designated as the Coast Ranges-Sierran Block (CSB) fault, the GVFS extends for several hundred miles from the southern SJV in Kern County (approximately 5 miles southeast of Lost Hills) northward to the northern Great Valley in Tehama County. The Caltrans 2007 Deterministic Peak Ground Acceleration map (Caltrans 2007b), however, shows the southern delineation of the GVFS about 34 miles to the northwest terminating about 2 miles south of Kettleman City in King County, near the intersection of I-5 and Highway 41. This revised interpretation of the GVFS southern trace is consistent with USGS and CGS interpretation (USGS a). The GVFS is not delineated on CGS Map Sheet 54 - Simplified Fault Activity Map of California (CGS a).

The USGS fault database (USGS a) maps the GVFS as being comprised of 14 segments ranging between approximately 10 to 35 miles in length, with most lengths approximately 20 miles. The most southern segments of the GVFS, Segments 13 and 14, are considered the likely sources of both the 1983 Coalinga M6.4 and 1985 Kettleman M6.2 earthquakes and are, thus, considered capable seismic sources in accordance with HST criteria. The Caltrans 2007 fault database (Caltrans 2007a) assigns a magnitude of the maximum earthquake (defined by moment magnitude, M_w) of 6.5 and 6.4 to Segment 13 and 14, respectively.

Ortigalita Fault

The General Plan for Fresno County provides a general description of the Ortigalita Fault, located within about 54 miles of the FB Section. “The Ortigalita fault zone is approximately 50-miles long, originating near Crow Creek in western Stanislaus County and extending southeast to a few miles north of Panoche in western Fresno County. Most of the fault is considered active due to displacement during Holocene time” (Fresno County 2000).

Further details are provided by the USGS. “The Ortigalita fault zone is a major Holocene dextral strike-slip fault in the central Coast Ranges that is an eastern part of the larger San Andreas fault system. The Ortigalita fault zone is characterized by en echelon fault traces separated by pull-apart basins” (USGS b).

Divided into four sections, the southernmost section of the fault, designated the Little Panoche Valley section, is closest to the FB Section and is considered to have been active in late Holocene time (USGS b). While slip rates are unknown, USGS advises that “the recurrence interval for the entire Ortigalita fault zone is about 2-5 k.y. [2,000 to 5,000 years].” A minimum vertical slip rate of 0.01-0.04 mm/yr is also reported, and while not documented, the dextral slip component is considered to be probably greater than the vertical component (USGS b).

San Joaquin and O’Neill Faults

The San Joaquin and O’Neill faults are located east of the Ortigalita fault. Bartow described the San Joaquin fault as a fault zone largely covered over by younger alluvial deposits.

> The San Joaquin fault zone is marked by a series of east-facing scarps and offset Quaternary depositional surfaces that were interpreted as evidence of down-to-the-east normal faulting. Along much of the zone’s length, however, the inferred faults are covered by upper Pleistocene and Holocene alluvium, so that there is some question about both the continuity and dip of the faults. (Bartow 1991)

The O’Neill fault, located between the Ortigalita and San Joaquin faults, is described by Bartow as a system of bedding-plane slips caused by upward flexure of strata.

> This [O'Neill] fault system consists of numerous northeast-dipping faults that offset Quaternary pediment surfaces by as much as 100 m [300 feet] The faults are apparently bedding-plane slips in the underlying Great Valley sequence that formed in response to the strong bending of the upturned strata. These faults caused offsets of Quaternary erosion surfaces and their associated deposits that lie across the beveled edges of the Great Valley sequence. (Bartow 1991)

The Caltrans 2007 fault database (Caltrans 2007b) assigns movement of the O'Neill Fault as being Late-Quaternary, while the San Joaquin Fault is considered to be Holocene. The database assigns these faults M_w's of 6.7 and 6.9, respectively.

Nunez Fault

The Nunez Fault is located approximately 6 to 7 miles northwest of Coalinga (Fresno County 2000), about 48 miles from the FB Section. URS (2006) note its relation to the 1983 Coalinga earthquake and rupture extent. "The fault is about 2.6 miles long and is considered active based on surface rupture associated with the 1983 Coalinga earthquake. The fault is divided into two north and south trending segments. About 2.1 miles of right-reverse surface rupture occurred on the segments. Total displacement and timing of past fault movements are poorly constrained."

Foothills Fault System

URS (2001) describe characteristics of the Foothills fault system.

> The Foothills fault system is a major north-northwest trending group of normal faults that extend along the western Sierra Nevada from north of Oroville southward to Fresno. … Geologically recent displacement on these faults appears to be normal, down-to-the-southwest, with individual fault offsets of less than 0.15 m (0.5 foot). The recurrence time between faulting events appears to be very long, on the order of tens and perhaps hundreds of thousands of years (Laforge and Ake 1999). The fault system consists of a number of relatively short, discontinuous faults. The limited rupture length of individual faults means that they are only capable of generating M_w's of 6.5. (Laforge and Ake 1999)

The General Plan for Fresno County further describes the southern portion and its activity.

> The southern part of the Foothills fault system, located approximately 70 to 80 miles north of the City of Fresno, includes the Bear Mountains fault and the Melones fault zone, as well as numerous smaller, but related faults. According to CDMG data, these faults have not shown any activity during the last 1.6 million years; however, geologic investigations of the seismic safety of the Auburn Dam site suggest that these faults are potentially active. Therefore, the possibility exists that earthquakes could occur on these faults. (Fresno County 2000)

Round Valley / Hilton Creek Fault

Berry (1997) described the Round Valley and Hilton Creek faults as " two major range-front faults in the Sierra Nevada frontal fault system …" Both are described as high-angle, down-to-east normal faults (USGS b). Based on analysis of fault scarps and faulted surficial deposits, Berry (1997) interpreted Holocene movement was possible on both faults but considered slip rates could be twice as high on the Hilton Creek fault. The analysis also suggested possible vertical slip during each faulting event in the order of 5 to 10 feet and that the faults could move together. Berry suggests a possible repeat time for faulting of between 2000 to 4000 years.

The Hilton Creek fault is associated with ground surface rupture during four M_w 6+ earthquakes that occurred in May 1980, with vertical slip rates estimated to range from 0.9 mm/yr to 4.2 mm/yr (USGS b).

The Caltrans 2007 fault database (Caltrans 2007a) designates the Round Valley fault as a Holocene fault while the Hilton Creek fault is designated a historic fault. A magnitude of the maximum earthquake (M_w) of 7.0 is assigned to the Round Valley fault and 6.7 to the Hilton Creek fault.

Clovis Fault

The General Plan for Tulare County describes some characteristics of the Clovis Fault, located approximately eight miles northeast of the FB Section.

> The Clovis Fault is considered to be active within the Quaternary Period (within the past two million years), although there is no historic evidence of its activity, and is therefore classified as "potentially active." This fault lies approximately six miles south of the Madera County boundary in Fresno County. Activity along this fault could potentially generate more seismic activity in Tulare County than the San Andreas or Owens Valley fault systems. In particular, a strong earthquake on the Fault could affect northern Tulare County. However, because of the lack of historic activity along the Clovis Fault, inadequate evidence exists for assessing maximum earthquake impacts. (Tulare County 2010)

According to the Fresno County General Plan, the Clovis Fault is "believed to be located approximately five to six miles east of the City Clovis, extending from an area just south of the San Joaquin River to a few miles south of Pancher Creek." Although movement in Quaternary time is not considered to have occurred, the fault is still considered "not necessarily inactive" (Fresno County 2000).

Corcoran Clay Fault Zone

The Corcoran Clay deposit is the thickest and most widespread clay deposit in the SJV, serving as an aquitard to an overlying unconfined aquifer and an underlying confined aquifer (CH2M 2003). Based on drilling and geophysical data, Saleeby and Foster (2003) have undertaken preliminary mapping of this deposit and interpreted (in conjunction with clusters of low to intermediate magnitude seismicity) rapid slope changes in the contoured surface, sharp bends in the contour lines, and missing strata in drill hole logs as evidence of faulting. Figure 3.5-1 indicates the estimated extent of faulting, defined here as the Corcoran Clay Fault Zone (CCFZ), together with contours of the top of the Corcoran Clay deposit (green lines) as well as the unmapped/inferred normal faults (red lines) interpreted by Saleeby and Foster (2003). One of the more striking features of the Corcoran Clay Fault Zone is the fault-bounded, 200-foot deep graben (shown in yellow) in the vicinity of Pixley and Alpaugh. As discussed in Section 5.2.2, this down-throw structure appears to be influencing the shape and location of subsidence bowls between Pixley and Delano.

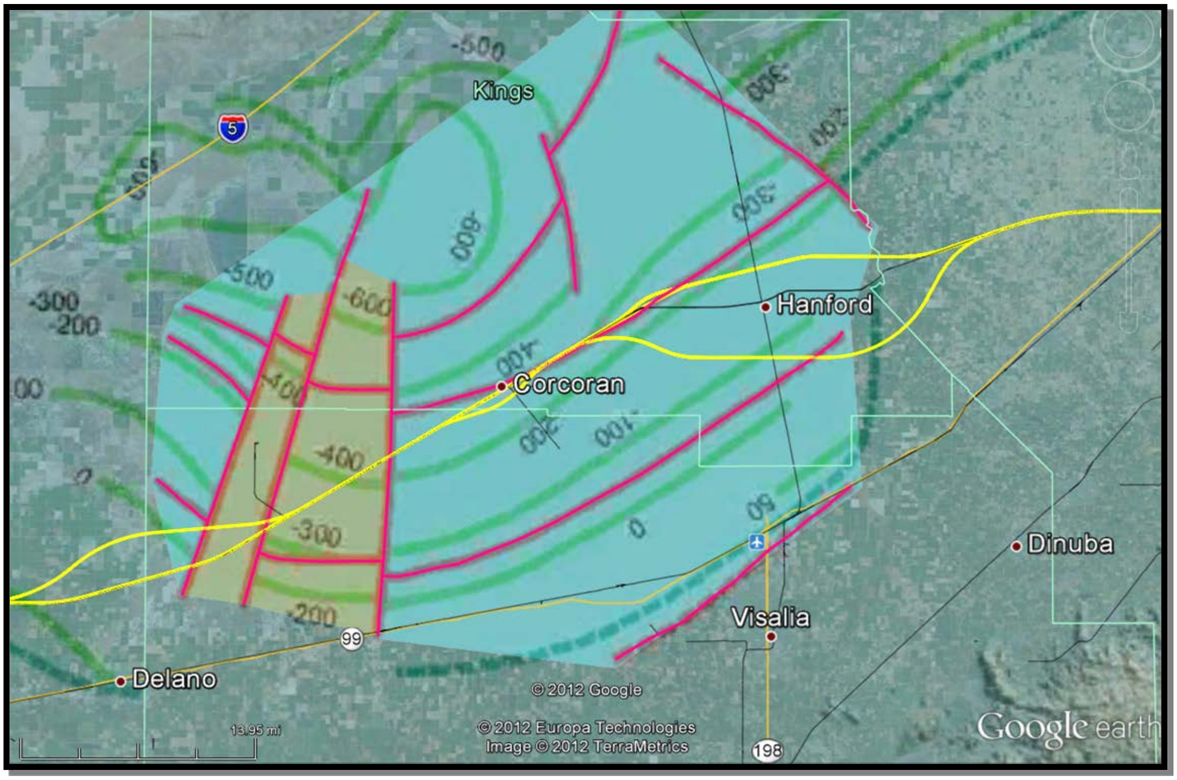

Figure 3.5-1
Structure and Contours of Corcoran Clay (Saleeby and Foster 2003)

Owens Valley Fault Zone

In 1872, the Owens Valley Fault Zone generated one of the largest historical earthquakes in California. The fault zone is located approximately 90 miles to the east of Fresno. Vittori et al. further describe its location and the extent of the 1872 rupture.

> Owens Valley is a 170 km [106 mile] long late Neogene graben at the boundary between the Sierra Nevada and Basin and Range Provinces that extends southward from Bishop to the Owens Lake-Coso area. It also lies in the narrow Eastern California Shear Zone (active geodetic strain rate approximately 6-8 mm/yr). In 1872, during a M 7.4-7.6 earthquake, a 116 km [72 mile] segment of the Owens Valley fault zone (OVFZ) ruptured with up to 10 m [33 feet] dextral-slip locally. (Vittori et al. 2003)

Bryant and Sawyer (2002) divide the fault zone into northern and southern sections, the latter defining the extent of surface faulting associated with the 1872 event. The northern section is considered to have exhibited Holocene movement but this is not quantified. The southern section, extending from near Klondike Lake to south of Owens Lake, is characterized by slip rates ranging between 1.2 and 3.6 mm/yr and a recurrence interval of between 3,000 and 5,000 years.

Kern Canyon Fault

The Kern Canyon Fault (KCF), dipping to the southwest, extends north nearly 100 miles, intersecting Lake Isabella Dam and then following the Kern River on the eastern flank of the Greenhorn Mountains and the Great Western Divide. Nadin and Saleeby suggest that it is active.

> Along the 140-km-long [87-mile-long] KCF, batholithic and metamorphic rocks were displaced up to 16~km [10~miles] in apparent dextral strike slip during at least three

> discrete phases of deformation throughout the past ~90~Myr. [...] The KCF has been considered inactive since 3.5~Ma based on a dated basalt flow reported to cap the fault. However, we believe this basalt to be disturbed, and several pieces of evidence support the idea that the KCF has been reactivated in a normal sense during the Quaternary. Fresh, high-relief fault scarps at Engineer Point in Lake Isabella and near Brush Creek, suggest recent, west-side-up vertical offset. And seismicity in the area hints at local motion. (Nadin and Saleeby 2005)

Kern Front Fault

There are apparently two separate interpretations of the location of the Kern Front Fault (KFF) within the fault databases reviewed (see Figure 3.5-2). The eastern trace extends from just north from Oildale approximately 6 miles to its intersection with the Poso Creek Fault, according to the USGS and the SCEC online interactive map and according to other sources such as Bartow (1991) and Jennings (1994). These sources locate the fault generally parallel to the Premier Fault (which follows Highway 65) and offset to the east 2 to 3 miles, roughly following the eastern flank of the Kern Front oil field. The KFF, as well as the nearby New Hope Fault and Premier Fault, have been creeping since the late 1940s, because of extraction of oil from the sub-surface rock formations, according to the SCEC and CGS, and were designated as earthquake fault zones (EFZs) under the AP Earthquake Fault Zoning Act. This fault trace of the KFF is shown in the foreground of Figure 3.5-2.

The second interpretation of the KFF is according to the Caltrans 1996 Seismic Hazards Map (Caltrans 1996) and appears to encompass a system of faults bounding the western flank of the Tehachapi foothills extending nearly 26 miles along Highway 65 from just north of the intersection with Highway 99 to about 6 miles north of the Kern/Tulare county line. This system of faults includes the Premier and New Hope Faults and a number of faults named only according to their proximity to Rag Gulch in the USGS database. This system of faults also appears on CGS Map Sheet 54 (CGS Online a) and is the zone highlighted in green on Figure 3.5-2. The actual trace of the KFF shown on the Caltrans 1996 Seismic Hazards Map appears to be generally located across this fault's system rather than a strict interpretation of any specifically mapped lineaments. Hence, it would be more appropriate to call this the KFF Zone (KFFZ) to distinguish it from the actual KFF that was zoned under the AP Act in 1984.

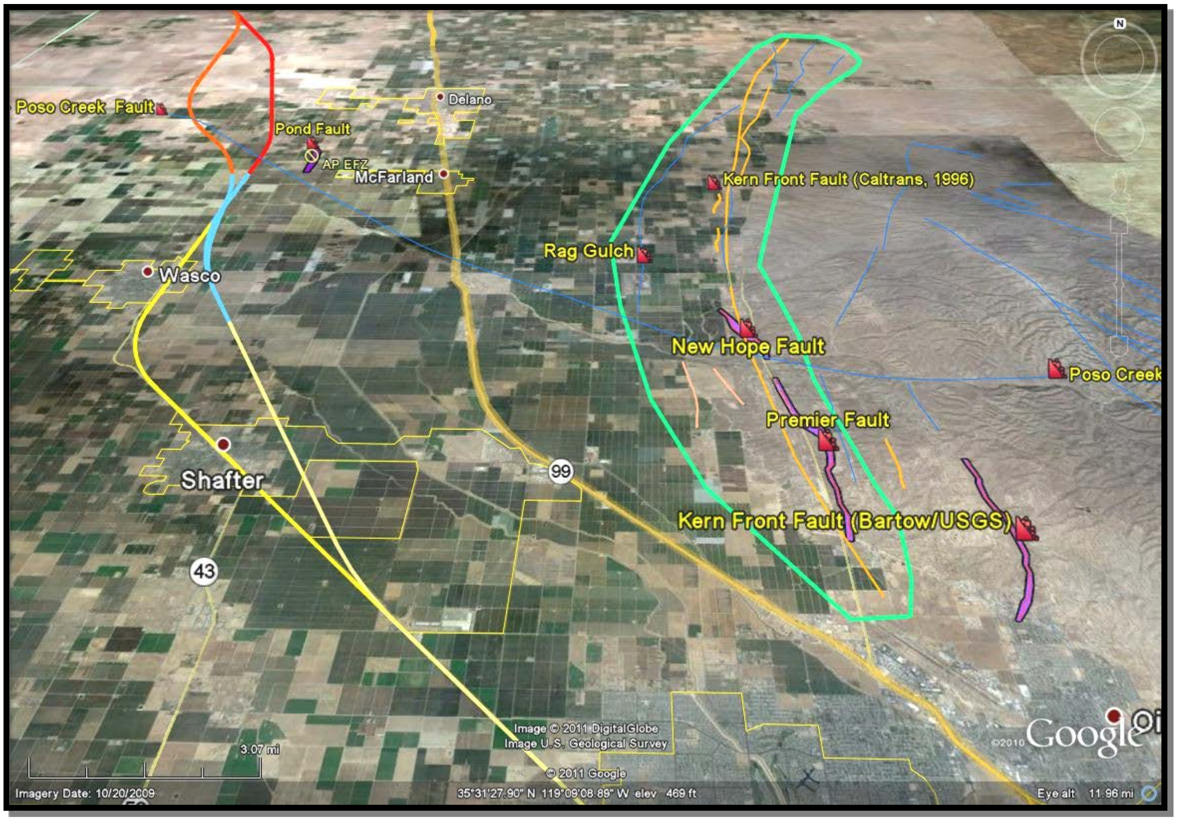

Figure 3.5-2
Kern Front Fault Limits and Historical Seismic Activity

According to the Caltrans 1996 Seismic Hazards Map, the KFF Zone is also a significant potential seismic source with an assigned M_w of M6.25. Moreover, the KFF was considered to be the causative fault for the governing seismic event by the widely used software, EQFault (Blake 2000), on a number of projects reviewed in the Bakersfield area including: the Westside Parkway Segments 2 and 3 (Kleinfelder 2008a; Kleinfelder 2008b); the Aquatic Ice Center (SEI 2002) and; the Cingular Wireless Communications Facility (URS 2003). On the other hand, EQFault lists the White Wolf as the controlling seismic source on the Mohawk Street Improvements project (Dokken 2008) and the Kern Front Fault does not appear on the Caltrans 2007 Deterministic PGA Map (Caltrans 2007b), which is the updated version of the 1996 Seismic Hazards Map, nor is it referenced in the 1997 UBC or the current IBC.

Epicenters of earthquakes in the vicinity of the KFF Zone with magnitudes greater than M_w 3.5 are also shown on Figure 3.5-2. Only one M_w 3.5 hypocenter, from October of 1982, was located in the zone. Apart from the CGS fault evaluation reports conducted for the zoning of the KFF, New Hope and Premier faults, no other specific data on other faults within the KFF Zone was located.

Kern Gorge Fault

The Kern Gorge Fault (KGF) lies about 14 miles to the northeast of Bakersfield and trends in a north west to south east east–west to northwest direction. The western trace intersects the eastern trace of the Poso Creek Fault. Thus, some sources, such as the City of Bakersfield General Plan (City of Bakersfield 2002), have erroneously combined these two faults under the singular name Poso Creek Fault. The SCEC references the Poso Creek Fault and Kern Gorge Fault together (SCEDC d) but distinct from each other, listing the Kern Gorge Fault as a late

Quaternary fault and the Poso Creek Fault as a Quaternary fault. Both the 1996 Caltrans Seismic Hazard Map (Caltrans 1996a) and the 2007 Caltrans Deterministic PGA Map (Caltrans 2007b) show the Kern Gorge Fault as a potential seismic source. The Caltrans 2007 fault database (Caltrans 2007c) suggests the KGF is normal fault with a 45 degree SE dip and an M_w of 6.6; the 1996 Caltrans map assigns the KGF an M_w of 7.0. On the other hand, this fault does not appear in the output of the EQFault (Blake 2000) database of any of the geotechnical design reports for the public or private projects in the vicinity of Bakersfield that were reviewed. Given that the Kern Gorge Fault appears in virtually every database it must be considered a "capable" fault.

Southern Sierra Nevada Fault (Independence Section)

The USGS describes the Southern Sierra Nevada fault zone as "a zone of high-angle normal faults that bound the eastern front of the southern Sierra Nevada from Owens Valley to the southern end of the range, north of the Garlock fault" (Sawyer 1995). The reported length of the fault zone varies between approximately 125 and 150 miles (Sawyer 1995; SCEDC e). The northernmost fault portion, designated the Independence fault, has cumulative vertical displacement of approximately 5,900 feet (Sawyer 1995). While noting the fault zone as poorly understood, SCEC (SCEDC e) assign a probable maximum magnitude of earthquake between M_w 6.0 to 7.1 and a likely slip rate less than 1 mm/yr.

Oil Field Fault Zone

The Oil Field Fault Zone (OFFZ) is shown on the 1996 Caltrans Seismic Hazard Map (Caltrans 1996) and CGS Map Sheet 54 (CGS Online a). Figure 3.5-3 shows a system of faults (within the green boundary) that include the north and south traces (shown in orange) according to the 1996 Caltrans Seismic Hazard Map. The Caltrans lineaments do not appear to be actual mapped fault traces but merely representative of the fault traces in the zone. According to USGS, traces of faults in the OFFZ overlap and bound the Unnamed 1952 Fault AP Zones (shown in purple) to the extent that the two systems are hardly distinguishable from one another. USGS traces of these faults are shown in blue on Figure 3.5-3 north of the alignment.

The OFFZ is separated into a north and south zone on the 1996 Caltrans Seismic Hazard Map, both with an M_w of 6.25. The southern fault extends to within 4000 feet of the HST just east of Edison. Both faults are of the normal type according to Caltrans. Neither the north or south OFFZ Caltrans faults (shown in orange) appear in any other seismic hazards database as potentially active seismic sources. Moreover, it can be inferred that the OFFZ has been de-rated as it does not appear on the 2007 Caltrans Deterministic PGA Map (Caltrans 2007b).

Based on review of EQFault (Blake 2000) data output for various projects in the Bakersfield area, the OFFZ is not considered a potentially active seismic source in the database for this widely used software. Accordingly, it appears that the standard of practice prior to 2007 was to disregard these faults as potential seismic sources. This appears to be further justified by their elimination from the 2007 Caltrans Fault Database (Caltrans 2007c) and the 2007 Deterministic PGA Map (Caltrans 2007b).

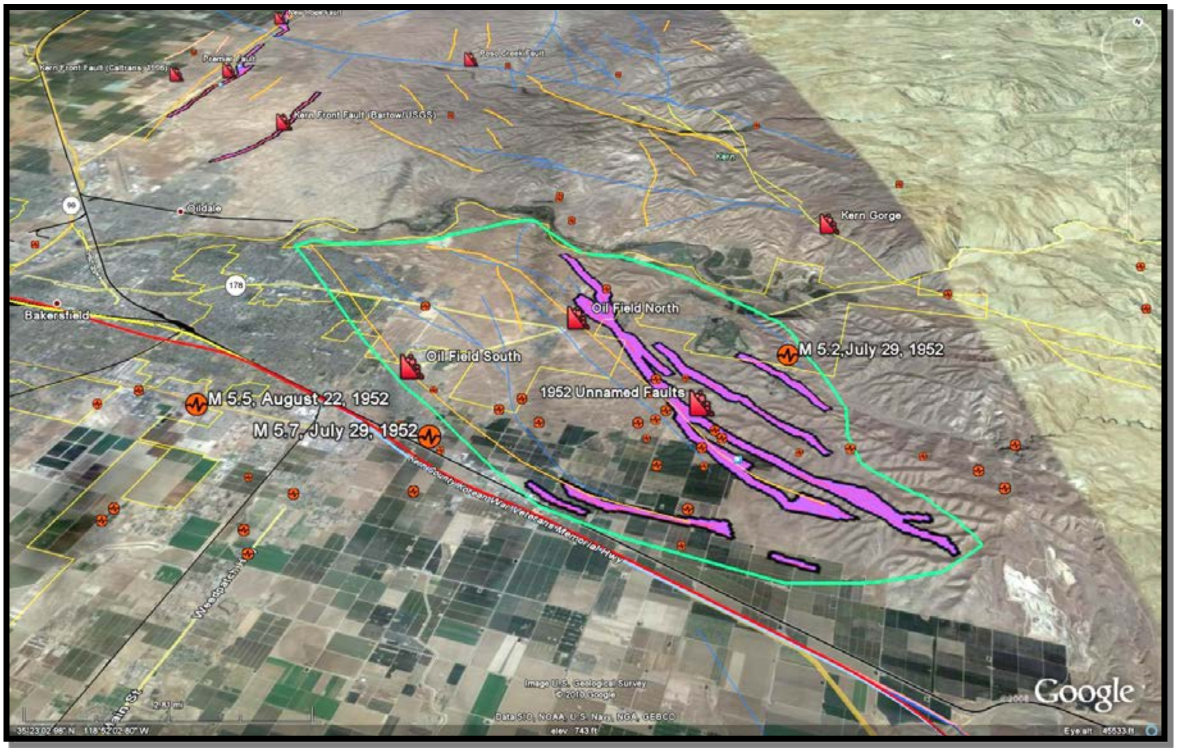

Figure 3.5-3
Oil Field Fault Zone Limits and Historical Seismicity

While the engineering community apparently does not consider the OFFZ fault zone to be an "active" or "potentially active" seismic source, the historical seismic activity and historical seismically induced ground rupture this zone has produced call for a closer evaluation. Figure 3.5-3 shows the epicenter locations of historical earthquakes with magnitudes ranging from M_w 3.0 to M_w 5.7. The three largest earthquakes shown in the figure occurred between July 29, 1952, and August 22, 1952, and ranged in magnitude from M_w 5.2 to M_w 5.7; they are considered aftershocks to the July 22, 1952, M_w 7.8 Kern County earthquake and were responsible for an additional $10M of damage ($82M in 2010 dollars) and two fatalities.

Garlock Fault

SCEDC describes the prominence of the Garlock Fault and its earthquake potential.

> The Garlock fault zone is one of the most obvious geologic features in southern California, clearly marking the northern boundary of the area known as the Mojave Block, as well as the southern ends of the Sierra Nevada and the valleys of the westernmost Basin and Range province. While no earthquake has produced surface rupture on the Garlock fault in historic times (although cracks opened along a short segment of the fault in 1952, due to the shaking of the Kern County earthquake, and groundwater removal has also triggered slip in the Fremont Valley area), there have been a few sizable quakes recorded along the Garlock fault zone. The most recent quake was a magnitude M_w 5.7 near the town of Mojave on July 11, 1992. It is thought to have been triggered by the Landers earthquake, just two weeks earlier. At least one section of the fault has shown movement by creep in recent years. These facts, along with the freshness of scarps left behind from previous ruptures and the ongoing seismicity associated with the fault zone, leave little doubt that the Garlock fault zone will rupture again in the future. (SCEDC f)

While the Garlock Fault is regarded as a major Holocene fault (Bryant 2000), slip rates vary as discussed by Miller et al. "In contrast to the relatively fast slip rate implied by geologic relations (3.8 mm/yr minimum, 7 mm/yr if estimates of fault initiation are correct) and paleoseismic results (5-7 mm/yr), GPS [global positioning system] baselines that cross the Garlock Fault suggest a very low sinistral slip; of the order of 1-2 mm/yr" (2001). This is in agreement with data obtained from an interferometric synthetic aperture radar (InSAR) study. InSAR is now a proven technique for mapping ground deformation using data from aircraft and satellites Figure 3.5-4 below shows an InSAR image of crustal deformation across the Mojave Desert between 1992 and 2000. Had there been any creep along the Garlock Fault (GF) during this time frame, there would have been color differential from one side of the fault to the other. Instead, the InSAR image shows that there is ground strain accumulating transverse to the GF along a line from the Blackwater Fault Zone (BWFZ) to the Little Lake Fault Zone (LLFZ). This structure is within the Eastern California Shear Zone (ECSZ) discussed below. Scientists speculate that there may be a cyclic nature to the accumulation and dissipation of strains between the GF and ECSZ.

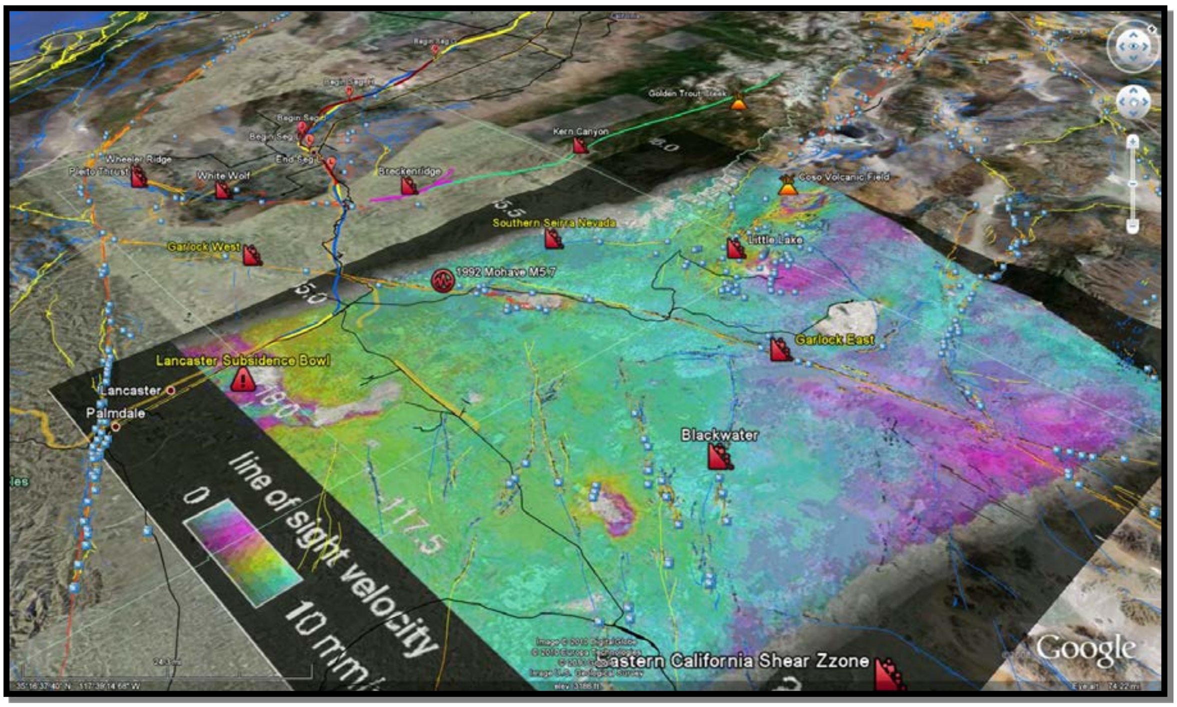

Figure 3.5-4
InSAR Image of Garlock Fault and ECSZ (modified after Plezter et al. 2001)

Traces of the Garlock Fault that pass through the Honda Proving Center near Koehn (dry) Lake about 20 miles northeast of the City of Mojave have seen movement in historic times according to the USGS database (Bryant 2000). The best evidence for recurrence and time to last event comes from the El Paso Peaks area. Two events are documented in the El Paso Peaks area during the last 550 years, and one may be as young as 200 years. Recurrence interval estimates range from 700 to 1200 years and are not highly periodic making prediction of a recurrence difficult (McGill and Rockwell 1998).

White Wolf Fault

The White Wolf Fault is listed as a potential seismic source in every fault database examined for this report and every project in the Bakersfield area that was reviewed. The significance of this fault is aptly described in the City of Bakersfield General Plan.

> The White Wolf Fault is a southeast dipping, left lateral oblique reverse fault 45 miles long (Warne 1955). This fault was recognized by its topographic expression by A. C. Lawson in 1906. On July 21, 1952, the White Wolf Fault ruptured, producing an earthquake of magnitude 7.5 and subsequently an extensive sequence of aftershocks. …
>
> At its northeast end, the fault is first evident in lower Tehachapi Canyon. It trends South 50 degrees west along the steep, northwest facing slopes of Bear Mountain to Comanche Point. From there it extends across the southern end of the San Joaquin Valley [SJV] to Wheeler Ridge. Indirect evidence suggests that the fault may possibly extend further towards the San Andreas fault. On the basis of aftershock hypocenter (epicenter) locations, the dip of the fault has been determined as 60 to 70 degrees to the southeast. Surface exposures of the fault show highly variable dips.
>
> The White Wolf Fault is thought to have initiated in Miocene time; it has been active for most if not all of the Pliocene, Pleistocene and Holocene epochs. Total uplift of the southeastern block is of the order of 10,000 feet; left lateral offset is no more than 2,000 feet. The detailed displacement history of the fault is unknown except for its 1952 movement. (City of Bakersfield 2002)

Although the 1952 rupture indicated some left-lateral movement along the fault, the significance of lateral offset is likely to be small compared with the total vertical movement believed to have occurred on the fault to date (Bartow 1991).

Breckenridge Fault

The Breckenridge Fault extends north from the White Wolf Fault 10 to 11 miles, slightly overlapping the Kern Canyon Fault by about 2 to 3 miles. The KCF dips to the southwest while the Breckenridge Fault dip varies from vertical to steeply east-dipping. Some seismologists consider the Breckenridge (and Kern Canyon) faults as extensions of the White Wolf Fault.

The discovery of possible activity on this fault and its subsequent reclassification were significant considerations in reassessing the risk of failure of the Isabella Dam and potential for inundation in the Bakersfield area as discussed below. Consequently, both the Breckenridge Fault and KCF are listed in the City of Bakersfield General Plan (City of Bakersfield 2002) as potential seismic sources. CGS Map Sheet 54 (CGS Online a) designates these faults as pre-Quaternary but "not necessarily without future potential activity". The 2010 CGS Fault Activity Map and Explanatory Text now designate this fault as Holocene.

Pond Fault and Poso Creek Fault

The FB Section crosses the Poso Creek Fault (PCF), which is mapped as a concealed fault in the area where it crosses the HST and extends from the foothills at the western flank of the Tehachapi Mountains in a northwesterly direction to within 2.5 miles of the county line. At the FB Section crossing, the fault is located approximately one mile south of the town of Pond (see Figure 3.5-5). From the FB Section/fault crossing, the PCF extends concealed in a northwesterly direction approximately 5 miles, where it curves to the west another two miles to its mapped terminus (Jennings 1994). To the southeast of the FB Section/fault crossing, the fault extends concealed approximately 22 miles, where it crosses Poso Creek. To the southeast of the creek, the fault continues unconcealed, where it meets the Kern Gorge Fault within the vicinity of Pine Mountain. In this region, the fault is downthrown to the south and dips to the south (Jennings 1994).

The City of Bakersfield General Plan (City of Bakersfield 2002) lists the PCF as potential seismic source with an M_w of 7.0 and a peak bedrock acceleration ranging between 0.31 and 0.48 (this is consistent with the Caltrans 1996 Seismic Hazards Map fault parameters for the KGF). However,

the eastern trace of this fault, as delineated on Figure VIII-1 of the City of Bakersfield General Plan, actually follows the USGS trace of the KGF. Thus, it appears the PCF was confused with the KGF during the preparation of the City of Bakersfield General Plan. Although the KGF does appear on the 1996 and 2007 Caltrans fault maps, the Poso Creek fault does not, nor do these faults appear in the 1997 UBC or current IBC. Additionally, we have not found any indication that these faults are considered as either active or potentially active seismic sources in the EQFault software (Blake 2000) database based on review of geotechnical design reports for various private and public works projects in the Bakersfield area (Dokken 2008; Kleinfelder 2008a; Kleinfelder 2008b). Nor do these faults appear in any other database of potential seismic sources reviewed for this report.

The preponderance of the RC's research suggests that, while there is a potential for ground rupture on these faults associated with fluid withdrawal, they do not appear to be a significant seismic source. On the other hand, although no historical earthquakes with magnitude greater than M_w 4.0 have been associated with these faults, the PCF was considered to be a "capable fault" (according to NRC guidelines) under the 1974 Los Angeles Department of Water and Power (LADWP) study of the Pond fault discussed below (Holzer 1980).

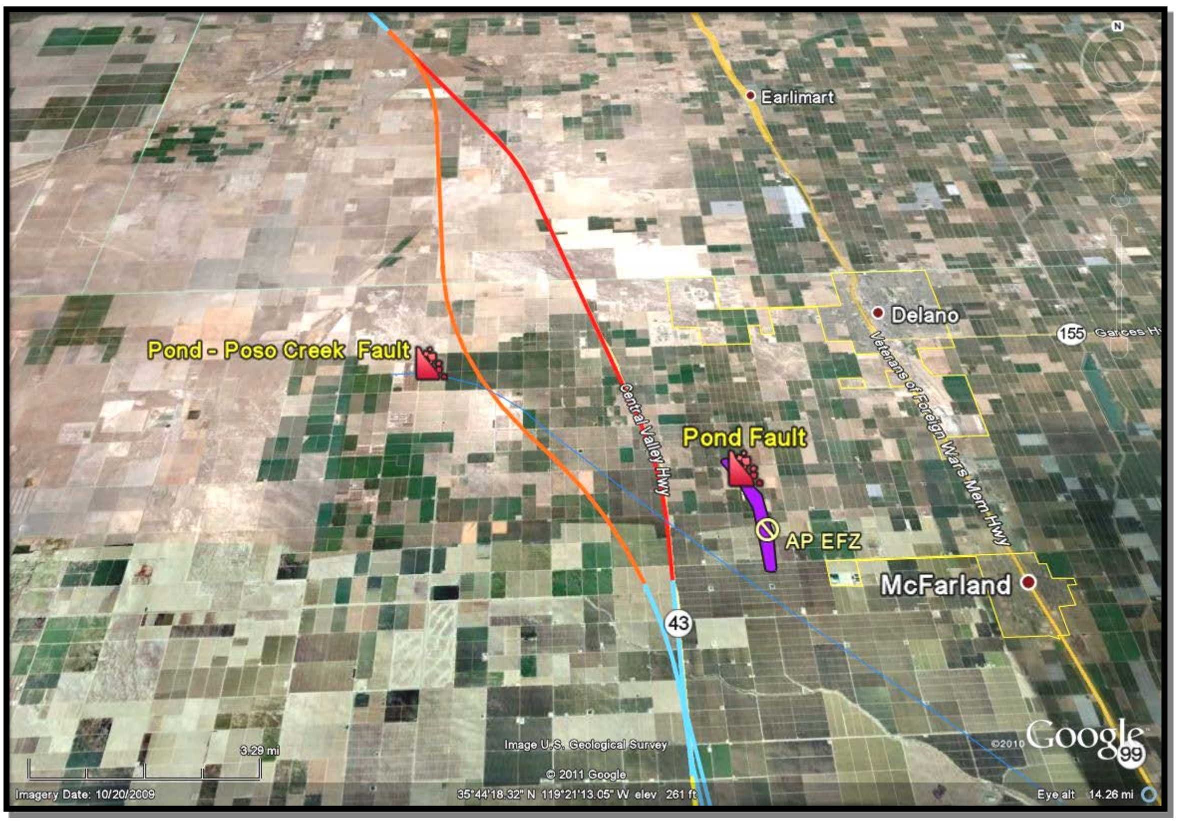

Figure 3.5-5
Traces of Pond-Poso Creek and Pond Faults (USGS Google Earth Faults)

Pond Fault

The Pond Fault is located to the east of the Town of Pond and consists of a 2/3 mile-wide zone of northwesterly trending normal faults (see Figure 3.5-5). The southernmost strand of the Pond Fault is located approximately 3 miles south of the community of Pond, and 2 miles east of the FB Section/fault crossing. The Pond Fault is interpreted to be a branch of the PCF, located to the

south and west. This fault segment was evaluated as part of a state-wide effort to evaluate faults for recent movement under the AP Act (Smith 1983).

Prior to the zoning study, the Pond fault was evaluated as part of an LADWP (1974) study for the siting of a nuclear power plant. Previous studies have shown that historical fault rupture (creep) has occurred on the fault, with repeated movement likely since Eocene and possibly since Paleocene time (LADWP 1974, p. 2.5E-67A).

The fault displacement is interpreted to be dip-slip, downthrown to the southwest, and dipping approximately 50 to 70 degrees from horizontal. The amount of total displacement along the width of the zone decreases to the northwest. The westernmost portion of the fault is interpreted to have the largest displacements. This segment of the fault, if projected to the surface at this location, would be in the vicinity of Lytle Avenue, located approximately 1.5 miles east of Pond and the HST alignment.

Observations from the LADWP study include the following:

- North–south trending zone of cracks crossing Elmo Highway, approximately 2.5 mile east of the HST alignment;
- A sag, cracks, and a scarp in the Peterson Road pavement, approximately 2.5 mile east of the HST alignment;
- An 8-foot-wide zone of cracked pavement, up to 2-inch-high scarp and broad sag across Lytle Road, located approximately 1.5 mile east of the HST alignment;
- A wide zone of dips in pavement across Benner Avenue, approximately 1 mile east of the HST alignment.

The conclusion of the LADWP study suggested that the Pond Fault was sufficiently well defined to warrant zoning, and the likely cause of the documented historic surface rupture may be the result of subsidence due to groundwater withdrawal (Bartow 1991).

From February 1977 to March 1979, vertical movement of fault scarps associated with the Pond Fault were monitored to determine if the source of movement was attributable to fluctuating groundwater levels (Holzer 1980). This indicated a strong correlation between fault movement and groundwater extraction during summer months, while lack of fault movement occurred during groundwater level recovery (see Figure 3.5-6). The likely cause of fault movement since the 1950s was therefore attributed to water level decline rather than seismic activity. The manner in which fault offset occurred was surmised as a localized effect, caused by the fault acting as a partial groundwater barrier, inducing water level differences across the fault zone that lead to different amounts of compaction on each side.

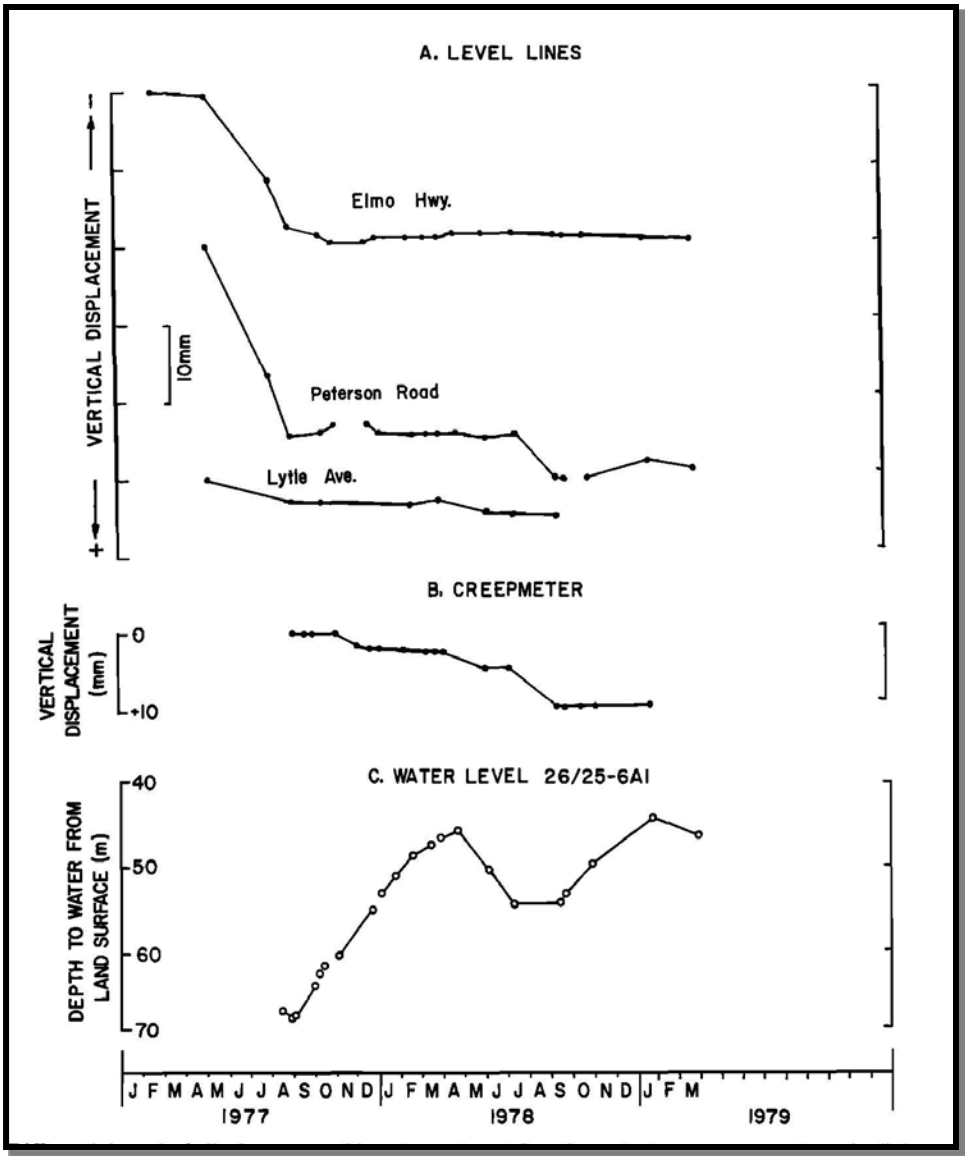

Figure 3.5-6
Pond Fault Ground Rupture Study (Holzer 1980)

Pleito Thrust Fault

Kern County Planning Department described the Pleito Thrust Fault (PTF) and its close association with the major tectonic forces at play at the southern end of the SJV.

> This thrust system … is also part of the Big Bend compression tectonics associated with the San Andreas Fault zone in this region. As the two major tectonic plates (North American and Pacific) collide, blocks of crust within each plate adjust to the compression by being thrust over or rotated relative to adjoining blocks. This low-angle, south-dipping series of thrust faults forms the north escarpment of the San Emigdio Mountains and the southern boundary for the Great Valley [SJV] geomorphic province. Tertiary sediments of the San Emigdio Mountains are thrust over Quaternary alluvial fan deposits. This fault system is considered to be active. (Kern County Planning Department 2009)

The PTF appears in nearly all the fault databases considered in this study although sometimes jointly with the nearby Wheeler Ridge Fault discussed below. According to the Caltrans 2007 fault database (Caltrans 2007C), this fault has a southward dip direction at a dip angle of 50 to 55 degrees and is capable of generating an M_w 7.0 earthquake. The eastern segment of the PTF is dated at less than 15,000 years old while the western segment is dated in the Holocene.

Wheeler Ridge Fault

Keller et al. (1998) describe the Wheeler Ridge Fault (WRF), located about 2 miles north of the PTF, as an active anticlinal feature with eastward migration.

> Wheeler Ridge is an east–west–trending anticline that is actively deforming on the upper plate of the Pleito–Wheeler Ridge thrust-fault system. Holocene and late Pleistocene deformation is demonstrated at the eastern end of the anticline where Salt Creek crosses the anticlinal axis. Uplift, tilting, and faulting, associated with the eastward growth of the anticline, are documented by geomorphic surfaces that are higher and older to the west.
>
> Faulting and associated folding is propagating eastward, as indicated by increases in both the degree of surface dissection and the degree of soil development from east to west. Distinct topographic areas having distinct degrees of surface dissection, bounded by tear faults, suggest that faulting and folding have propagated eastward in discrete segments.
>
> Numerical dates indicate (1) the anticline is propagating eastward at a rate of about 30 mm/yr (about 10 times the rate of uplift); (2) folding was initiated about 400 ka [400,000 years ago]; (3) a prominent wind gap was formed during Q3 time (about 60 ka) when an antecedent stream was defeated, forcing the stream east around the nose of the fold; today drainage through the ridge is by way of two antecedent streams (water gaps) east of the wind gap; and (4) the rate of uplift at the easternmost and youngest (past 1 k.y.) part of the fold is at least 3 mm/yr.

The WRF is listed in to the Caltrans 2007 fault database (Caltrans 2007a) as a reverse fault with a southward dip direction and dip angle of 45 degrees. Both the database and the 2007 Deterministic PGA Map (Caltrans 2007b) assign the WRF an M_w 6.8 magnitude for the maximum earthquake, while the 1996 Caltrans Seismic Hazard Map (Caltrans 1996) suggests M_w 7.0 is more appropriate.

Edison Fault

The Edison Fault is not generally considered active; however, there is a branch in the western trace of the fault, north of Edison, that extends into the AP Zone defined by the Unnamed 1952 Faults and has experienced Holocene offset and historical activity. In total, there are four possible traces of this fault (see Figure 3.5-7).

<u>The Wood and Dale vs. Bartow Traces</u>

A series of normal faults striking roughly parallel to the bedding of sedimentary rocks underlying the Edison area have been mapped by Wood and Dale (1964) and Bartow (1984), resulting in two conflicting fault traces. This normal fault complex, which includes the Edison fault, according to Wood and Dale's account, is situated approximately 0.5 miles southwest of Edison (Edison – South) and is delineated by a contrast in groundwater elevation on either side of the fault's presumed trace. Bartow's interpretation of the Edison fault trace places it approximately 0.5 miles northeast of the Edison (Edison – North 1) and places its terminus well within the complex of the 1952 Unnamed Faults and the associated AP EFZ north and northeast of Edison (Geomatrix 2006). The 1952 Unnamed Faults (discussed below) are of historic age and experienced ground rupture during the 1952 Kern County earthquake. These were designated as EFZ in the mid-1980s under the AP Act (Smith 1984).

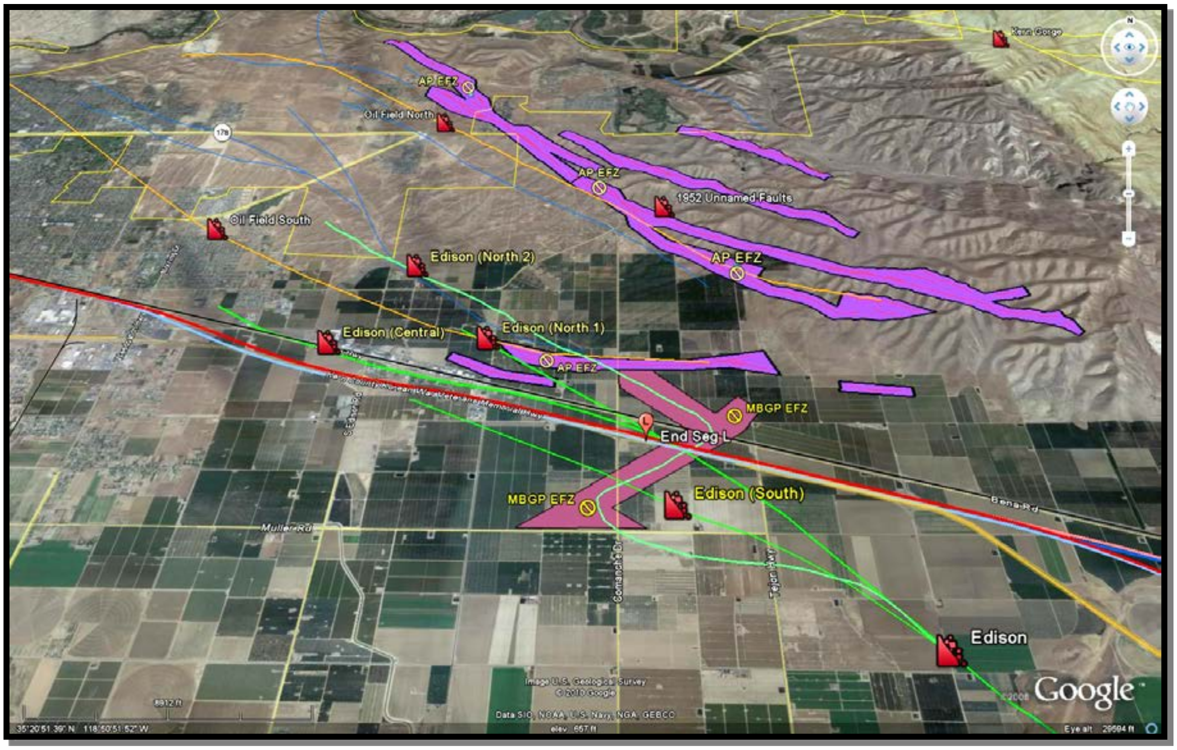

Figure 3.5-7
Possible Traces of Edison Fault Branches

These two interpreted traces of the Edison fault are referred to as the North Branch and South Branch of the Edison fault (Wood and Dale 1964; Bartow 1984). The location of the South Branch is supported by the 2010 CGS fault activity map (CGS 2010) and on that map is extended beyond what is shown in Figure 3.5-7 to about 1000 feet past Vineland Road. The Town of Edison is situated within the fault block bounded by the North and South Branches of the Edison Fault (Geomatrix 2006). Both branches of the Edison fault appear to be barriers to groundwater flow as shown in groundwater elevation maps produced by Wood and Dale (1964). These faults are normal faults dipping steeply northeast. If both Wood and Dale's and Bartow's interpretation of the Edison fault trace are combined on a common map, it is apparent that these two fault traces merge southeast of Highway 58. Both faults have the same sense of offset, which is northeast side down. Both the Northern and Southern Branches of the Edison Fault are designated Quaternary in age (Jennings 1994). The Southern Branch is concealed at the ground surface and has not shown historical displacement. The Northern Branch has a surface expression that shows offset of quaternary sedimentary units (Bartow 1984) "with a small segment showing historical offset" (Jennings 1994).

<u>The Working Group on California Earthquake Probabilities 2007 Trace</u>

A third interpretation of the location of the western trace of the Edison Fault is shown on Figure 3.5-7. as Edison (Central). This interpretation is derived from the project geographical information systems (GIS) files in the HST Project Solve database. Its trace is consistent with and likely derived from the trace preferred by the Working Group on California Earthquake Probabilities (WGCEP 2007). This trace crosses the FB Section at about 300 feet east of the end of the study area and the end of Subsection FB-L at about Tower Line Road. From there the fault trace extends toward the west, through the town of Edison, paralleling the south side of Highway 58 and eventually crossing Highway 58 just west of Edison and east of Vineland Road.

04/02/2014 - RFP No.: HSR13-57

The MBGP/CDWR Trace

The fourth trace, Edison (North 2), is shown on Figure A6 of Appendix A as a groundwater barrier along with the White Wolf Fault and the Springs Fault. The source of this trace was not directly verified at the time of this study but it does coincide with an EFZ shown on Figure VIII-2 of the City of Bakersfield General Plan (City of Bakersfield 2002) that crosses the alignment at about the same location as the WGCEP trace and presumed Bartow traces. This trace, designated the MBGP (Metropolitan Bakersfield General Plan) EFZ is not an official EFZ under the AP Act but appears to have been locally identified during preparation of the General Plan. Its significance is corroborated by Jennings' (1994) assessment of "historic activity" at or near this EFZ.

Southern Sierra Nevada Fault (Haiwee Reservoir)

The Southern Sierra Nevada Fault (SSNF) is a normal fault with a 60 degree dip to the east and is also shown on **Figure 3.5-4** toward the western margin of the InSAR image. The SSNF bounds the western side of the SNFZ and has been listed in the City of Bakersfield General Plan (City of Bakersfield 2002) as one of the potential faults that pose a regional seismic threat. The SSNF appears in most every fault database. As such it demands consideration in the seismic hazard evaluation of the study area. Caltrans (2007a) assigns this fault a Mw of M7.3.

Unnamed 1952 Faults E/NE of Edison

The 1952 Kern County Earthquake exposed a number of unknown faults in the Arvin-Bakersfield Area. The faults were exposed through surface ground rupture immediately following the earthquake. Documentation on the offsets and displacements that occurred during the event were difficult to locate during this study. Several of these unnamed faults located to the east of Edison, extend within 1500 feet of the north side of the alignment and are shown on AP seismic hazard maps produced by the DMG and various government agencies within Kern County. The AP EFZs associated with these faults are shown on Figure 3.5-3 and Figure 3.5-7 above. At least one map published in the City of Bakersfield General Plan (City of Bakersfield 2002) shows the AP zone associated with these faults traversing to the south side of the FB Section and Highway 58 then dovetailing into the western reaches of the Edison Fault. This zone is shown as MBGP EFZ in Figure 3.5-7.

Eastern California Shear Zone (ECSZ) and Sierra Nevada Fault Zone (SNFZ)

Miller et al. (2001) note that the Eastern California Shear Zone (ECSZ) initially included faults within the Mojave Desert but now also accounts for deformation north of the GF (see **Figure 3.5-5**) through to the Sierra Nevada Fault Zone (SNFZ). The SNFZ is a broad zone of distributed shear along the eastern edge of the Sierra Nevada mountain block north and west of the GF, demarcating the western margin of the Basin and Range geologic province. Discrepancies between plate motion in Southern California (50 mm/yr) and the San Andreas Fault (35 mm/yr) have been resolved and attributed to observed strain occurring across the shear zones. Observations and kinematic analysis of the relative velocities of GPS stations between 1993 -1998 indicate that strain rates across the ECSZ were on the order of 14/mm year (Miller et al. 2001). Researchers evaluating InSAR data determined that a zone within the ECSZ sheared at a rate of about 7mm/yr at a depth of approximately 16,500 feet between 1992 and 2000 (Pelzter et al. 2001).

Greeley Fault System

Described by Bartow (1991) as "an en echelon set of northwest-trending normal faults", the Greeley Fault System (GFS) is located west of Bakersfield and near the center of the SJV. Bartow discussed the origin of the GFS that "may have had its origin in the Cretaceous or earliest Tertiary and shows no offset of horizons younger than early Miocene" (1991).

Bartow continues with discussion of the tectonic stress regime. “North-trending normal faults of pre-Miocene age (including northwest-trending faults like the Greeley and Pond) indicate approximate east–west to northeast–southwest extension in the early Tertiary; these faults may be the only manifestation of a north–south regional compressive stress at that time, although there may be some possibility of minor right-lateral, strike-slip on northwest-trending faults like the Greeley fault (1991).

Bartow also discusses the type of fault movement assessed from a detailed nuclear power plant siting investigation.

> An intensive study of the Greeley Fault system for a proposed nuclear power plant site astride the northern segment of the fault, based on seismic-reflection profiles and oil well data … concluded that the movement has been normal (down-to-the-east) and that there is no evidence of lateral displacement. This study did not consider the possibility of reverse movement; however, the geometry of the Greeley structure, as seen on seismic-reflection sections, is sufficiently different from reverse fault structures … to seriously weaken the reverse fault hypothesis for the origin of the Greeley structure. (Bartow 1991)

The Greely Fault System does approach relatively close to the FB Section in the Wasco area but does not cross the alignment at any specific location, nor is the fault considered active or potentially active. Accordingly, this fault is judged to have a low risk of appreciably impacting the performance of the HST and, thus, is not considered a capable fault.

InSAR Faults

NASA and the USGS (USGS FS 069-03 2003) monitored subsidence in the Bakersfield area over a two-year period between August 1997 and September of 1999 using satellite InSAR. InSAR images can be combined using interferometric analysis to measure surface deformation remotely from space. This technology is not only useful in assessing areal land subsidence but also reveals that subsidence patterns may indicate the presence of faults that may not be otherwise detectible. Figure 3.5-8 shows an InSAR image of the broad areal subsidence occurring north of Bakersfield between 1997 and 1999 (USGS) occurring in the Kern River and Kern Front oil fields. The USGS image shown in Figure 3.5-8 was scaled and stretched using Google Earth to determine the significance of several unidentified, north–south-trending faults inferred by the subsidence fringes.

According to the InSAR image data, two relatively well-defined, unidentified faults flank the western boundary of the observed subsidence field. The northern unidentified fault appears to be associated with the KFFZ, which divides the Kern Front oil field to the west and Kern River oil field to the east.

The locations of the inferred InSAR faults extend south generally along Chester Avenue across Subsection FB-L.

The faults shown in Figure 3.5-8 trend southeast–northwest, as does the Bakersfield Subsidence Bowl. The alignments skirt the southern margins of the bowl. The parallel trend of the bowl and known faults in the area, such as the Greeley Fault, suggest that the shape of the bowl could be related to concealed faults in the vicinity. Movement on the southerly fault trace identified in the image below could possibly occur by the same mechanism that causes movement on the KFFZ.

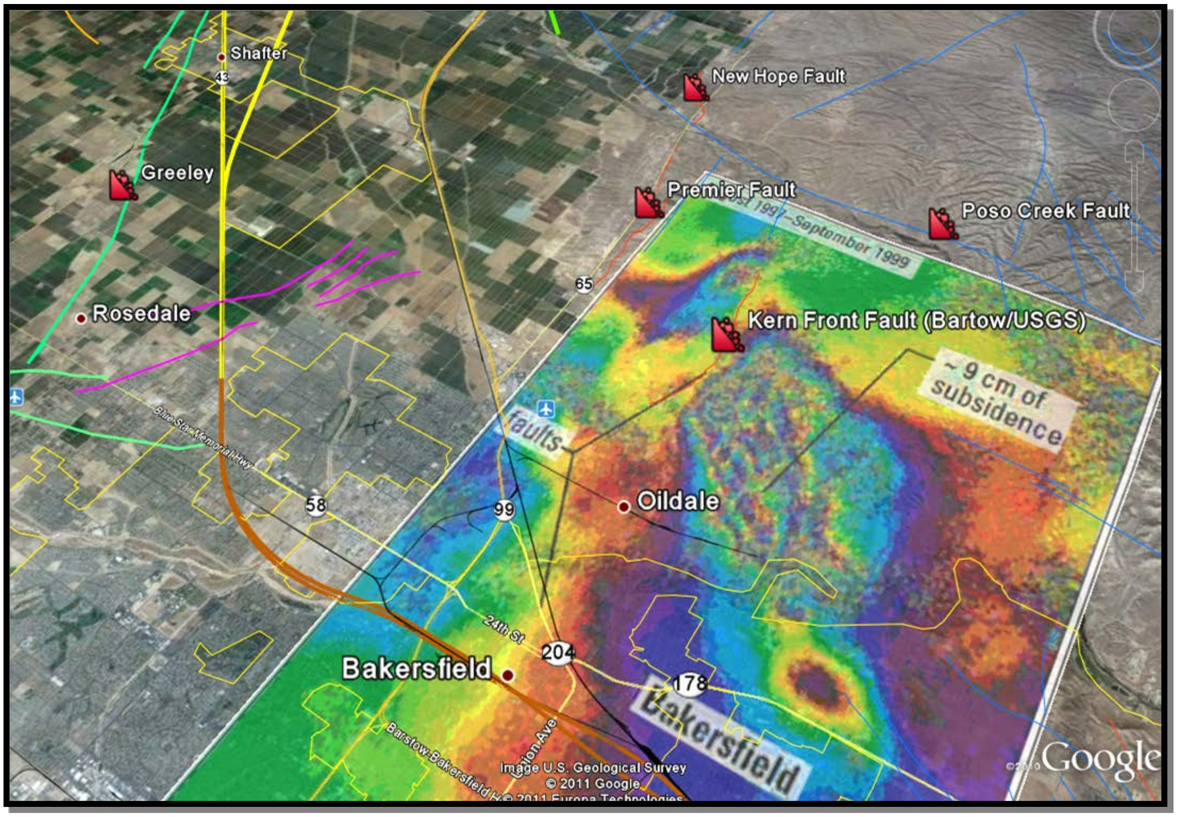

Figure 3.5-8
InSAR Unknown Faults (modified after USGS FS 069-03, 2003)

3.6 Physiography and Topography

The topographic provinces discussed in this report are based on the USACE topographic map (1962) and the physical model GIS layer. These reference sources cover the FB Section of proposed alignment in its entirety but are out of date. Project-specific surveying data and light detection and ranging data, to be completed in the future, will be used to more fully describe the physiography and topography of this section of the alignment.

The general topography of the Central Valley comprises low elevation, low relief terrain at an elevation of generally less than 400 feet ASL, with the notable exception of the Sutter Buttes in the Sacramento Basin.

The HST section between Fresno and Bakersfield is located fully within the SJV at an elevation between 200 feet and 400 feet ASL and passes through gently undulating low relief terrain with shallow natural slopes through the urban areas of Wasco, Shafter and Bakersfield. Through Subsection FB- L (Bakersfield South) from the alignment's intersection with Highway 99 to the terminus of the study area east of Edison the topography gently rises from about elevation (EL) 400 feet to 680 feet ASL as it flanks the southern foothills of the Tehachapi Mountains. The general physiography and topography of the SJV within the study area is shown on Figure 3.6-1.

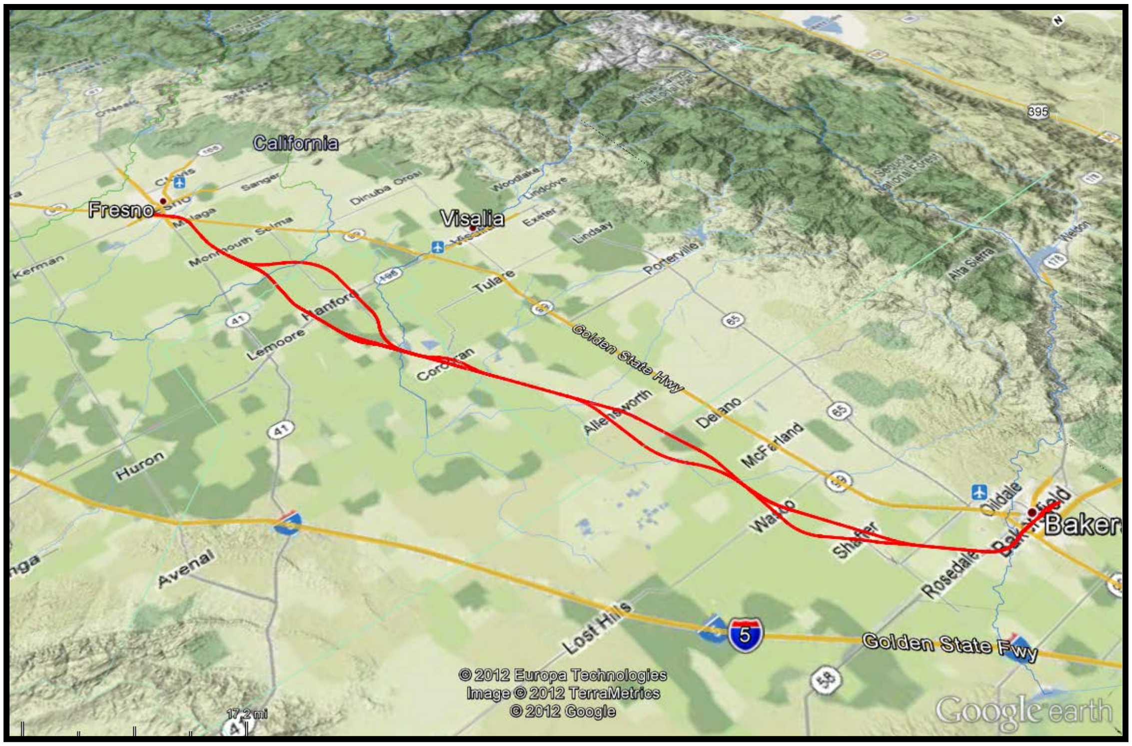

Figure 3.6-1
General Study Area Physiography and Topography

Superimposed upon this large-scale, relatively flat topography is a localized topography of river systems caused by recent incisions. This localized topography is comprised of short steep river/stream banks with channels at lower elevations relative to the surrounding areas. These channel bottoms range between wide relatively flat bottomed (with occasional rounded natural levees) and narrow gully type valleys depending on their age and the amount of flow.

3.7 Surface and Groundwater Conditions

The Great Valley actually comprises two elongated northwest to southeast-trending drainage basins. The Sacramento Basin, to the northwest, drains through the Sacramento River to the south and the San Joaquin Basin, to the southeast, drains either through the San Joaquin River to the north or through intermittent streams to seasonal lakes to the south. The watershed in the San Joaquin Basin is proximate to Fresno with water either draining to the north of Fresno to the San Joaquin River or to the south of Fresno to an internal drainage basin.

3.7.1 Climate

The presentation, in this section, on annual precipitation, daytime temperatures and potential evaporation is based on information from the California Department of Water Resources (CDWR), the HST Draft Water Quality Hydrology Technical Report (WQHTR, April 2010). This information is considered up-to-date and accurate.

> The climate within the project study area can be characterized as semi-arid, with the valley experiencing long, hot, dry summers and relatively mild winters. Based on these long-term records, the average annual temperature for the project study area ranges from 62.4 to 65.2 degrees Fahrenheit (°F), the minimum daily temperature ranges from 14 to 20°F, and the maximum daily temperature ranges from 112 to 116°F. (WQHTR 2010).

Table 3.7-1 and Table 3.7-2 below (WQHTR, April 2010) present the monthly temperature and precipitation data from the various weather stations on the northern part of the FB Section.

Table 3.7-1
Temperature Summary (Water Quality/Hydrology Technical Report)

Temperature (°F)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Fresno, California (1948-2005)													
Mean Monthly	46.0	51.1	55.3	61.2	68.8	76.0	81.8	80.0	74.9	65.4	53.7	45.9	63.3
Daily Max. Extreme	78.0	80.0	90.0	100.0	107.0	110.0	112.0	112.0	111.0	102.0	89.0	76.0	112.0
Hanford, California (1927-2005)													
Mean Monthly	45.0	50.2	55.0	60.9	68.2	74.7	80.0	78.2	73.0	64.2	52.5	45.1	62.4
Daily Max. Extreme	76.0	86.0	89.0	98.0	107.0	111.0	116.0 .	115.0	110.0	101.0	92.0	77.0	116.0
Visalia, California (1927-2005)													
Mean Monthly	46.4	51.6	56.3	61.9	68.6	75.6	80.9	79.3	74.3	65.8	54.4	46.7	63.4
Daily Max. Extreme	79.0	87.0	90.0	99.0	108.0	111.0	115.0	115.0	110.0	104.0	94.0	80.0	115.0
Corcoran, California (1948-2005)													
Mean Monthly	45.5	50.8	55.4	61.3	69.0	75.9	81.1	79.4	74.3	65.1	53.2	45.4	63.0
Daily Max. Extreme	75.0	81.0	88.0	100.0	107.0	114.0	115.0	112.0	109.0	105.0	89.0	78.0	115.0
Corcoran, California (1948-2005)													
Mean Monthly	45.5	50.8	55.4	61.3	69.0	75.9	81.1	79.4	74.3	65.1	53.2	45.4	63.0
Daily Max. Extreme	75.0	81.0	88.0	100.0	107.0	114.0	115.0	112.0	109.0	105.0	89.0	78.0	115.0
Wasco, California (1948-2005)													
Mean Monthly	46.0	51.5	56.5	62.4	69.8	76.9	82.3	80.5	75.3	65.7	83.8	45.9	63.9
Average Max.	56.1	63.5	69.8	77.31	85.5	93.5	99.3	97.5	91.9	81.9	67.2	56.6	78.3
Average Min.	35.8	39.5	43.5	47.9	54.2	60.4	65.4	63.4	58.7	49.6	40.4	35.2	49.5
Daily Max. Extreme	81.0	86.0	93.0	101.0	109.0	113.0	114.0	113.0	111.0	105.0	92.0	780	114.0
Daily Min. Extreme	19.0	22.0	26.0	31.0	39.0	43.0	49.0	46.0	41.0	29.0	23.0	14.0	14.0
Bakersfield, California (1937-2005)													
Mean Monthly	47.9	52.8	57.1	62.8	70.4	77.7	83.8	82.1	76.9	67.3	55.6	48.2	65.2
Average Max.	57.4	63.6	68.8	75.8	84.2	92.1	98.6	96.6	90.9	80.7	67.3	57.9	77.8
Average Min.	38.5	42.1	45.4	49.7	56.5	63.1	69.0	67.5	62.9	54.0	44.0	38.5	52.6
Daily Max. Extreme	82.0	87.0	94.0	101.0	107.0	114.0	115.0	112.0	112.0	103.0	91.0	83.0	115.0
Daily Min. Extreme	20.0	25.0	31.0	33.0	37.0	44.0	52.0	52.0	45.0	29.0	28.0	19.0	19.0

Notes: °F = degree(s) Fahrenheit
min. = minimum
max. = maximum
Source: Western Region Climate Center 2009.

Table 3.7-2
Average Monthly Precipitation (Water Quality/Hydrology Technical Report)

Station	Period of Record	Elev-ation (feet)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Fresno	1948-2005	340	2.13	1.88	1.97	1.00	0.37	0.15	0.01	0.01	0.17	0.53	1.17	1.58	10.94
Hanford	1927-2005	250	1.58	1.53	1.46	0.72	0.24	0.08	0.01	0.01	0.13	0.37	0.82	1.28	8.22
Visalia	1927-2005	330	1.94	1.88	1.72	0.98	0.33	0.09	0.01	0.01	0.13	0.51	1.03	1.62	10.26
Corcoran	1948-2005	200	1.51	1.35	1.18	0.65	0.23	0.05	0.01	0.01	0.16	0.32	0.76	0.99	7.20
Wasco	1948-2005	350	1.29	1.30	1.25	0.68	0.24	0.10	0.01	0.02	0.13	0.31	0.67	0.83	6.83
Bakersfield	1937-2005	490	1.08	1.17	1.16	0.68	0.22	0.08	0.01	0.04	0.11	0.30	0.61	0.80	6.23

Notes:
Precipitation measured in inches.
°F = degrees Fahrenheit
Source: Western Regional Climatic Center 2009.

Wind in the SJV is generally from the northwest, typically blowing up toward the mountains in the early mornings and downward toward the valley in the evenings. The valley floor often experiences fog in late November through mid-February (after Water Quality/Hydrology Technical Report and USACE 1996).

The FB Section of the HST is characterized by long, dry summers and intermittent wet periods. Based on the long-term records of precipitation the average annual precipitation ranges between approximately 6.23 to 10.94 inches with most (over 80%) of precipitation falling between November and April. "In the Sierra Nevada, the majority of the mean annual precipitation falls as snow and ranges from 20 inches in the foothills to over 80 inches at higher elevations. The Coast Ranges west of the valley floor have annual precipitation ranging from 10 to over 20 inches" (Water Quality/Hydrology Technical Report). Figure 3.7-1 shows the average annual precipitation throughout most of the study area.

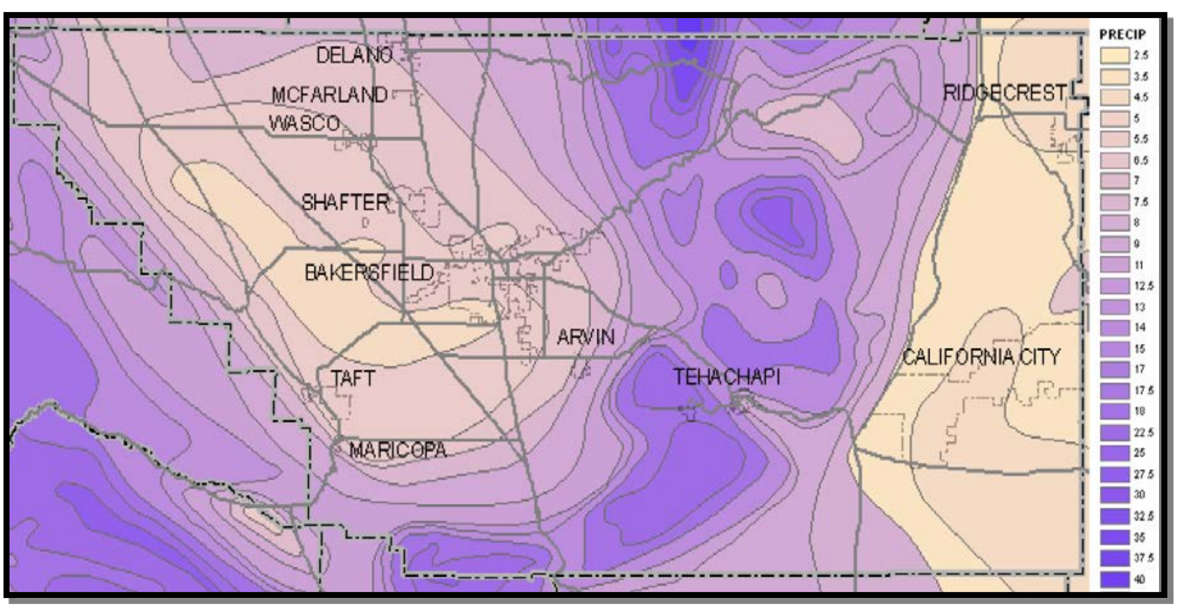

Figure 3.7-1
Kern County Average Annual Precipitation (KMHP 2005)

3.7.2 Rivers and Lakes

The information regarding the fluvial and lacustrine features along the alignment is based on the USACE topographic map (1962), Weissmann et al. (2005) and other published literature. These reference sources, covering the FB Section of the proposed alignment are reasonably relevant however, project specific surveying data, light detection and ranging data and aerial photography is necessary to fully describe the fluvial systems particularly recent channel migration. Figure A5 Appendix Aof Appendix A shows the surface river channels relative to the proposed alignment.

Between approximately 650,000 and 760,000 years ago Lake Clyde occupied the Great Valley including both the Sacramento Valley and the SJV. Fossil evidence indicates that the lake was of shallow depth with large lateral extents. This is confirmed by the extensive presence of the lacustrine Corcoran Clay Member of the Tulare and Turlock Lake Formations. The lake drained around 600,000 years ago with the establishment of the current SJV drainage system that discharges to the Pacific Ocean through San Francisco Bay.

The northern portion of the SJV is drained to the delta by the San Joaquin River and its tributaries, the Fresno, Merced, Tuolumne, and Stanislaus Rivers. The southern portion of the valley is internally drained by the Kings, Kaweah, Tule, and Kern Rivers. These rivers flow into the Tulare drainage basin which includes the intermittent lake beds of the former Tulare, Buena Vista, and Kern Lakes. These lakes no longer exist due to upstream storage of winter precipitation in dams and diversions for agriculture within the SJV. Waters from these reservoirs are used primarily for agricultural purposes. The rivers themselves are mostly dry in their lower reaches during the summer months (Weissmann et al. 2005). Winter flows can be significant with localized flooding in many areas through the SJV along the route of the proposed alignment.

The Tulare Lakebed is located west of Corcoran. The Buena Vista and Kern Lake beds are located southwest and south of Bakersfield, respectively. Until the development of intensive agriculture and the subsequent damming and water diversion, seasonal precipitation, predominately drainage from the Sierra Nevada, would flow via the rivers of the South SJV to collect in topographic sinks creating large seasonal/ temporary lakes near Corcoran and Bakersfield. The approximate location of these lakes, although dried now, can still be discerned on geological maps defined as areas of Quaternary Lake deposits (Ql).

The FB Section is entirely within the Tulare Lake Basin. The major surface water features in the Tulare Lake Basin include the Kings, Kaweah, Tule, and Kern rivers, which all have their sources in the Sierra Nevada to the east and flow west. Table 3.7-3 below (WQHTR 2010) details the water bodies crossed by the proposed alignment.

> The Kings River originates in the Sierra Nevada within the Kings River watershed and flows southwest approximately 125 miles from the foothills to the Tulare Lake bed. Elevations within the Kings River watershed range from 832 to 11,599 feet. The North, Middle, and South Forks of the Kings River converge in the foothills upstream of Pine Flat Dam. Upstream of Pine Flat Dam, the Kings River drains approximately 1,545 square miles (USACE 1999). Downstream of the dam, the Kings River flows through canals and levee systems and splits into multiple channels as water is diverted for irrigation and flood control in the valley. (Water Quality/Hydrology Technical Report).

The Kaweah River, in Tulare County, originates in the Sierra Nevada and flows to Lake Kaweah, a reservoir formed by Terminus Dam. Elevations in the Kaweah River watershed range from 12,569 feet at the headwaters to 400 feet at the dam. The Kaweah River drainage area upstream from Terminus Dam covers approximately 561 square miles.

The Tule River originates in the Sierra Nevada Mountains and flows to Lake Success before entering the valley. The North, Middle, and South forks of the Tule River converge in the foothills upstream of Lake Success, the lake formed by Success Dam with a capacity of 82,300 acre-feet. The Tule River drainage area upstream from Success Dam covers approximately 393 square miles (USACE 1999). The headwaters of the Tule River are in the southern Sierra watershed, along with the headwaters of Deer Creek, White River, and Poso Creek. The total drainage area of the southern Sierra watershed is 665,473 acres (Jones and Stokes 2008). From Lake Success, the Tule River flows generally westward across the San Joaquin Valley floor to the Tulare Lake bed. (Water Quality/Hydrology Technical Report).

The Kern River headwaters are in the Sierra Nevada within the Kern River watershed. The watershed is characterized by steep river canyons and large mountains, and elevations range from 489 feet to 14,478 feet, with a mean elevation of 6,791 feet. The Kern River, its forks, and Lake Isabella are the major water features within the watershed (Jones and Stokes 2008). The Kern River flows generally southwest through the city of Bakersfield to the Buena Vista Lake bed. Isabella Dam was constructed in 1953 and is on the Kern River, approximately 35 miles northeast of Bakersfield. The Kern River drainage area upstream of Isabella Dam covers approximately 2,074 square miles (USACE 1999). The primary purpose of the dam and the reservoir created by the dam, Isabella Lake, is to provide flood control, and the dam is operated so that the maximum flow in the Kern River at the Pioneer Turnout near Bakersfield does not exceed the capacity of the river channel, which is 4,600 cfs (USACE 2008). Isabella Lake has a capacity of approximately 570,000 acre feet, and also provides water for irrigation (Gronberg et al. 1998). In the SJV, the Kern River is bordered by conveyance and diversion canals for much of its length, and its water is diverted for consumptive use or groundwater recharge (Jones and Stokes 2008).

Table 3.7-3
Water Bodies Crossed by the Proposed Alignments (WQHTR 2010)

Waterbody[3] (Name)	Type[1]	Approximate Milepost or Station (TBD)	Approximate Crossing Width[4] (feet)	Drainage Area (acres)	Crossing Method[2]
FMFCD Basin EE	B		800	2,270	
FMFCD Basin RR2	B		200	2,460	
Dry Creek Canal	C		<50	N/A	
Braly Canal	C		<50	N/A	
Fresno Colony Canal	C		<50	N/A	
North Central Canal	C		<50	N/A	
Central Canal	C		<50	N/A	
FMFCD Basin CE	B		1,000	535	
Harlan Stevens Ditch	C		<50	N/A	
Davis Ditch	C		<50	N/A	
Elkhorn Ditch	C		<50	N/A	
Cole Slough	I		50	TBD	Bridge
Murphey’s Slough	I				

Waterbody[3] (Name)	Type[1]	Approximate Milepost or Station (TBD)	Approximate Crossing Width[4] (feet)	Drainage Area (acres)	Crossing Method[2]
Dutch John Cut	I		100	TBD	
Kings River	I		50	TBD	
Riverside Ditch	C		<50	N/A	
Last Chance Ditch	C				
People's Ditch	C		<50	N/A	Bridge
East Branch of People's Ditch	C		<50	N/A	Bridge
Unnamed Irrigation Canal	C		<50	N/A	
Unnamed Irrigation Canal	C		<50	N/A	
Unnamed Irrigation Canal	C		<50	N/A	
Settler's Ditch	C		<50	N/A	2-42" Pipes
East Branch Lakeside Ditch	C		<50	N/A	2-42" Pipes
NoName Ditch	C		<50	N/A	2-42" Pipes
NoName Ditch	C		<50	N/A	2-42" Pipes
Melga Canal	C		<50	N/A	Bridge
NoName Ditch	C		<50	N/A	Bridge
NoName Ditch	C		<50	N/A	Bridge
Cross Creek	I		200	TBD	Bridge
West Branch Lakeland Canal	C		50	N/A	5x8 Double RCBC
NoName Ditch	C		<50	N/A	2-24" Pipes
Corcoran Reservoir/Ponds?			?	N/A	
Sweet Canal	C		<50	N/A	
Tule River	I		200	TBD	Bridge
Unnamed Irrigation Canal	C		<50	N/A	
Unnamed Irrigation Canal	C		<50	N/A	
Unnamed Irrigation Canal	C		<50	N/A	
Lakeland Canal	C		<50	N/A	Bridge
Deer Creek	I		<50	TBD	Bridge
White River	I		?	TBD	
Stream Crossing	I		<50	TBD	Bridge
Rag Gulch	I		<50	TBD	
Dyer Creek	I		<50	TBD	
Poso Creek	I		<50	TBD	Bridge

04/02/2014 - RFP No.: HSR13-57

Waterbody[3] (Name)	Type[1]	Approximate Milepost or Station (TBD)	Approximate Crossing Width[4] (feet)	Drainage Area (acres)	Crossing Method[2]
Unnamed Irrigation Canal (at Kimberlina Road)	C		<50	N/A	
Arvin Edison Canal	C		<50	N/A	
Friant-Kern Canal	C		75	N/A	
Emery Ditch	C		<50	N/A	
Cross Valley Canal	C		100	N/A	
Kern River[5]	P		650	TBD	
Carrier Canal	C		100	N/A	
Kern Island Canal	C		75	N/A	
East Side Canal	C		50	N/A	

Notes:
1 Type: B=drainage or recharge basin, C=irrigation canal, I=intermittent, P=perennial.
2 Based on HST Cross Drainage Table 2010-02-17.xls, HST Alignment C1 in February 17, 2010.
3 Features identified from review of USGS topographic maps and aerial photographs.
4 Crossing widths subject to change once HST alternative alignments are finalized.
5 HST alternative alignments do not cross perpendicular to the Kern River. Therefore, approximate crossing width is greater than the perpendicular width of Kern River.
FMFCD = Fresno Metropolitan Flood Control District
N/A = not applicable
TBD = to be decided
USGS = US Geological survey

3.7.3 Reservoirs and Ponds

A significant number of field-size water storage facilities created to store water for irrigation of local areas can be seen in topographical and geological mapping and aerial photography and were confirmed during the May 2010 field reconnaissance. Because of the constraints on access during the survey and on the sheer number of ponds adjacent to the alignment, not all the locations of the existing ponds have been confirmed. A review of historical USGS topographic maps dating from 1954, 1968, and 1973 revealed that the locations of these ponds vary over time, i.e., the ponds are periodically relocated. These maps show that there are nearly twice as many historical ponds as existing ponds in the reaches of the alignment that traverse open farm lands (see Figure 3.7-2).

Figure 3.7-2
Subsection FB-H Pond Hazards

Existing and historical ponds pose a particular hazard, in that soils in the vicinity are likely to be more saturated and weaker. Moreover, at the locations of historical ponds, the backfill was likely to be variable and was not likely compacted to any degree, which makes these areas prone to differential settlement and to reduced capacity for deep foundations. Therefore, it is critical to the long-term performance of the HST subgrade and deep foundations supporting viaducts to accurately locate and investigate these areas through further review of aerial photography and historical maps and by geotechnical investigation programs. This preliminary study identified 7 to 8 locations where existing or historical ponds pose a potential hazard to the various alignments; several of these are shown in Figure 3.7-2.

3.7.4 Evaporation Basins

Cultivation and irrigation of the SJV has mobilized salts stored in these soils and moved them toward the groundwater often creating conditions of shallow perched water of poor quality where soils are clayey. Many acres of basin and west side farmland have been affected by shallow saline groundwater.

An interim solution to this problem is disposal to evaporation basins. Currently, 4,800 acres of evaporation basins serve 46,000 acres of tile drained land in the Tulare Lake Basin.

The most significant evaporation basin hazard that this study identified is shown in Figure 3.7-3 and is located in Segment FB-G at the north and south ends of the Deer Creek Viaduct. The trapezoidal area at the south is nearly two miles wide at the base, transverse to the alignment, and about a half mile across, parallel to the alignment. Evaporation basins are likely to be highly saturated because of the amount of standing water at their perimeters and the periodic flooding as evidenced by the baked salts on the surface.

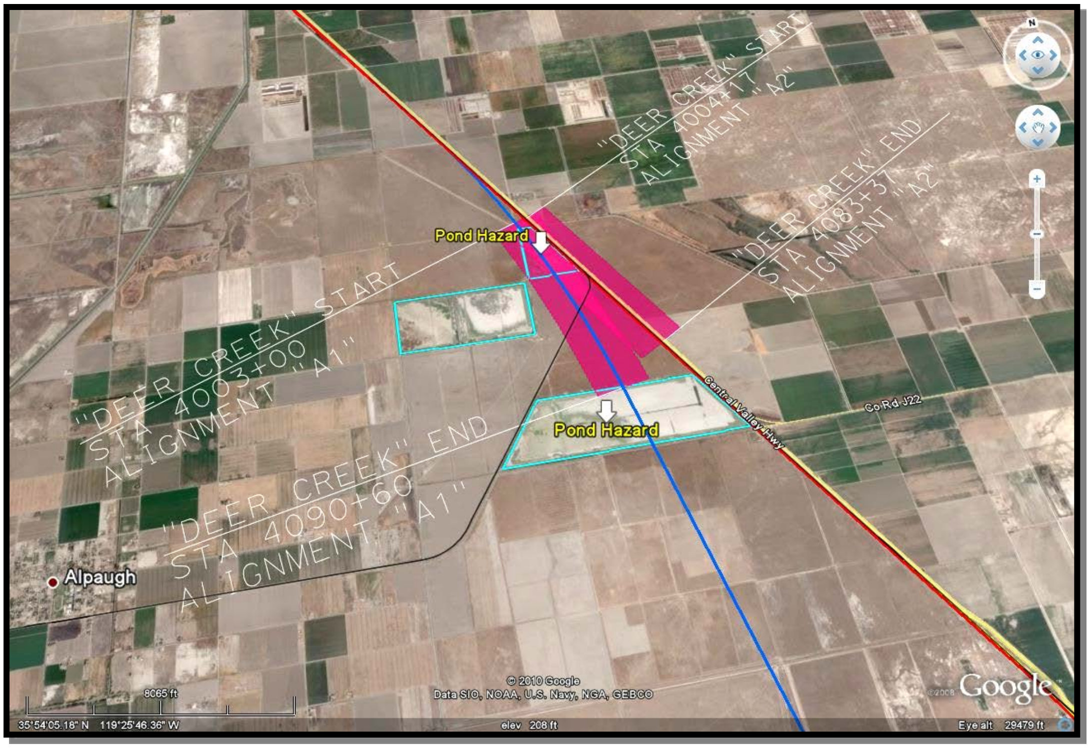

Figure 3.7-3
Deer Creek Viaduct Pond Hazards

3.7.5 Unconfined Groundwater

The groundwater region that the HST alignment passes through is known as the Tulare Lake Hydrologic Region. "Groundwater levels fluctuate with seasonal rainfall, withdrawal, and recharge. The large demand for groundwater has caused subsidence in some areas of the Valley, primarily along its western side and southern end (CDWR 2003). Depth to groundwater in the SJV ranges from a few inches to more than 300 feet. The project study area is within the SJV Groundwater Basin and crosses through five of its seven sub-basins: Kings, Tulare Lake, Kaweah, Tule, and Kern", (Water Quality/Hydrology Technical Report 2010).

Groundwater table data are based primarily on the CDWR Groundwater Basin Contour Maps but other published literature and online resources have been reviewed. Figure A6 Appendix Aof Appendix A shows the Contours of Depth to Groundwater relative to the proposed alignment published by the CDWR for 2005. These reference sources are reasonably up-to-date (5 years old) and cover part of the FB Section of the proposed alignment. Only limited, older (24 years old) contour data has been published between Corcoran and the Tulare/Kern County line and is shown Figure 3.7-4 as discussed below.

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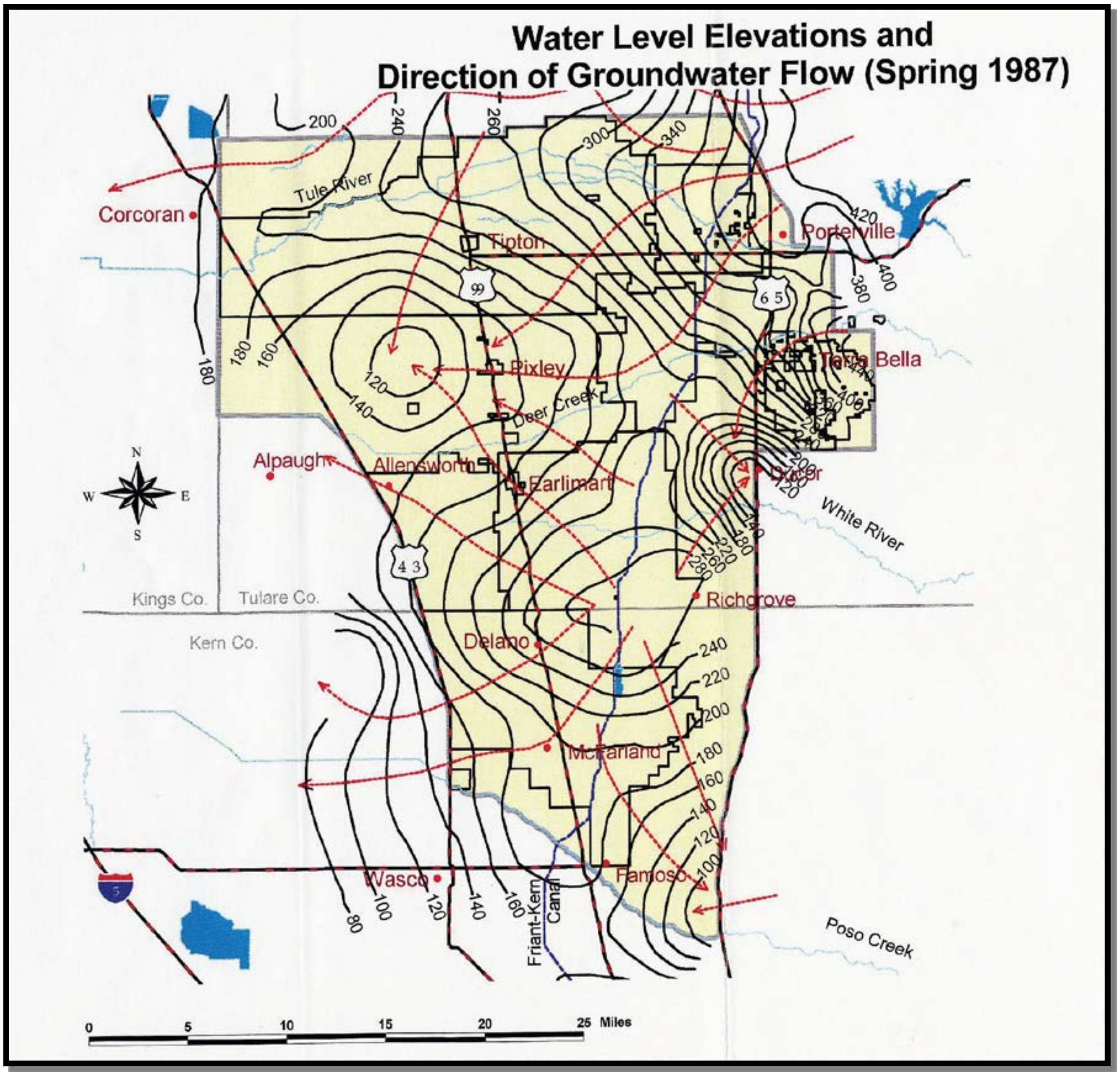

Figure 3.7-4
Segments FB-E, F and G: Groundwater Contours (after Quinn 2007)

As demonstrated by the hydrographs below, groundwater table elevations vary locally, seasonally and from year to year depending on climate conditions. There are instances on the hydrographs and in the historical bore log contained in the gINT database where shallower groundwater table elevations than those shown on Figure A6 of Appendix A are recorded. Overall, the data presented below indicates that recent (i.e. within the last 60 years) groundwater tables elevations peaked between 1984-88 and then again between 1998-01. Conversely, the lowest recent groundwater table elevations occurred during the droughts between 1976-78 and 1987-92.

The following discussion pertains predominately to Figure A6 of Appendix A and Figure 3.7-4 but also includes more recent information and well hydrographs from the online CDWR Water Data Library accessed in July of 2011 and January of 2012 (CDWR 2007). The preponderance of the hydrographs examined suggest that current groundwater table elevations are between 10 to 20 feet below those indicated on Figure A6 of Appendix A. According to the web site, red points on the hydrographs indicate less reliable data. References to ground surface elevations do not

necessarily reflect the existing ground surface elevations but rather to the ground surface elevations recorded on the CDWR web site. The web site states that most of the ground surface elevations are referenced to USGS 7.5-minute quads. As discussed in Section 5.2.4 existing grade may be substantially lower (up to 18 to 20 feet lower) due to subsidence that has occurred along the alignment. It is presumed that water surface elevations shown on the hydrographs are relative to ground surface elevations recorded on the CDWR web site and, therefore, estimations to the depth of groundwater are unaffected relative to existing grade.

Subsections FB-A through FB-F

The southern reach of the study area encompasses the Kings, Tulare Lake, and Kaweah sub-basins (CDWR, Bulletin 118). Groundwater table information for Subsection FB-A through FB- F is summarized as follows:

- Fresno Urban (FB–A): Groundwater in the unconfined aquifer is likely to be encountered approximately 100 feet below ground surface (bgs) through the town center, rising to 50 feet bgs to the south toward the Rural North (FB–B) subsection based on Figure A6 of Appendix A. Figure 3.7-5 shows a hydrograph of a well in Fresno along the HST alignment. This well is likely relatively typical of the groundwater table elevation fluctuations throughout Segment FB-A. The ground surface elevation is at this well is about 292 feet ASL indicating the current groundwater table is currently about 126 feet bgs at this location.

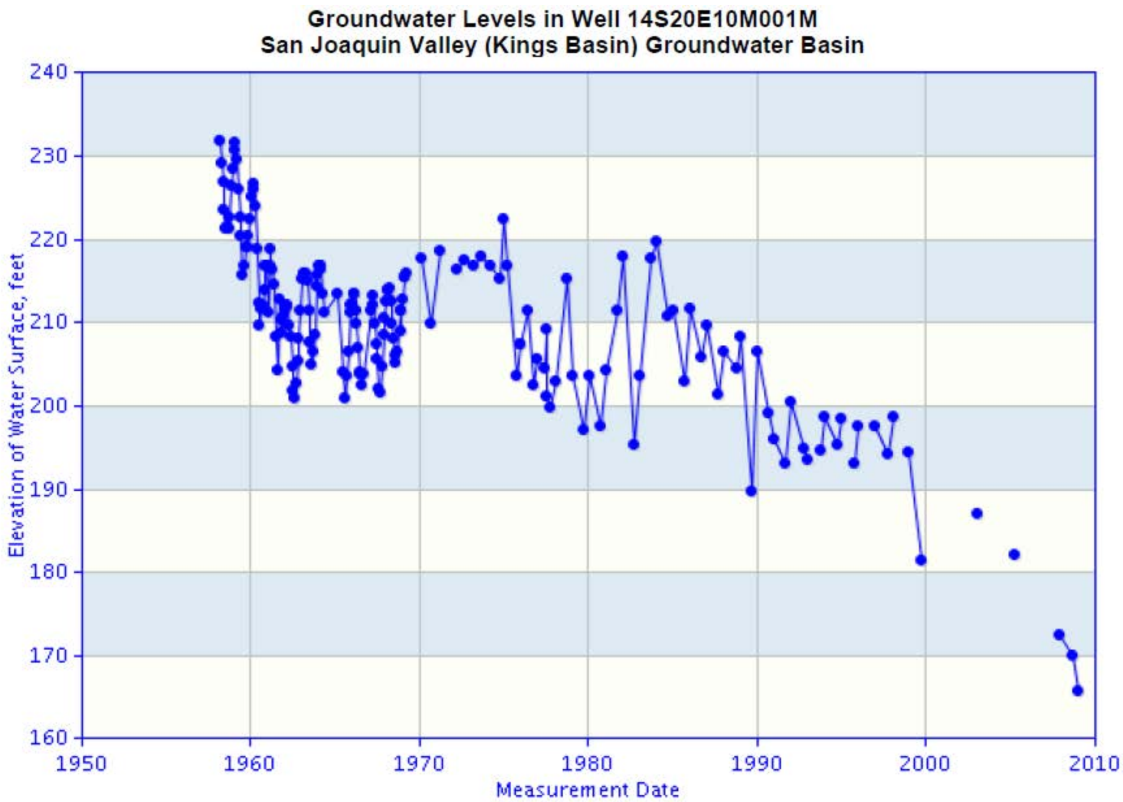

Figure 3.7-5
Fresno Water Well Hydrograph (CDWR 2011)

04/02/2014 - RFP No.: HSR13-57

- Rural North (FB–B): Groundwater in the unconfined aquifer is likely to be encountered between 50 feet to 70 feet bgs based on Figure A6 of Appendix A. Figure 3.7-6 shows a hydrograph of a well in the vicinity of the Town of Bowles along the HST alignment. This well is relatively typical of the groundwater table elevation throughout Segment FB-B. The ground surface elevation is at this well is about 275.6 feet ASL indicating the current groundwater table is currently about 75 feet bgs at this location. A hydrograph of another well at East Morton Avenue and South Maple, about three miles north of the alignment with similar features to the Bowles hydrograph below indicates the current groundwater table is about 63 feet bgs and further validates the relative depth of the contours on Figure A6 of Appendix A.

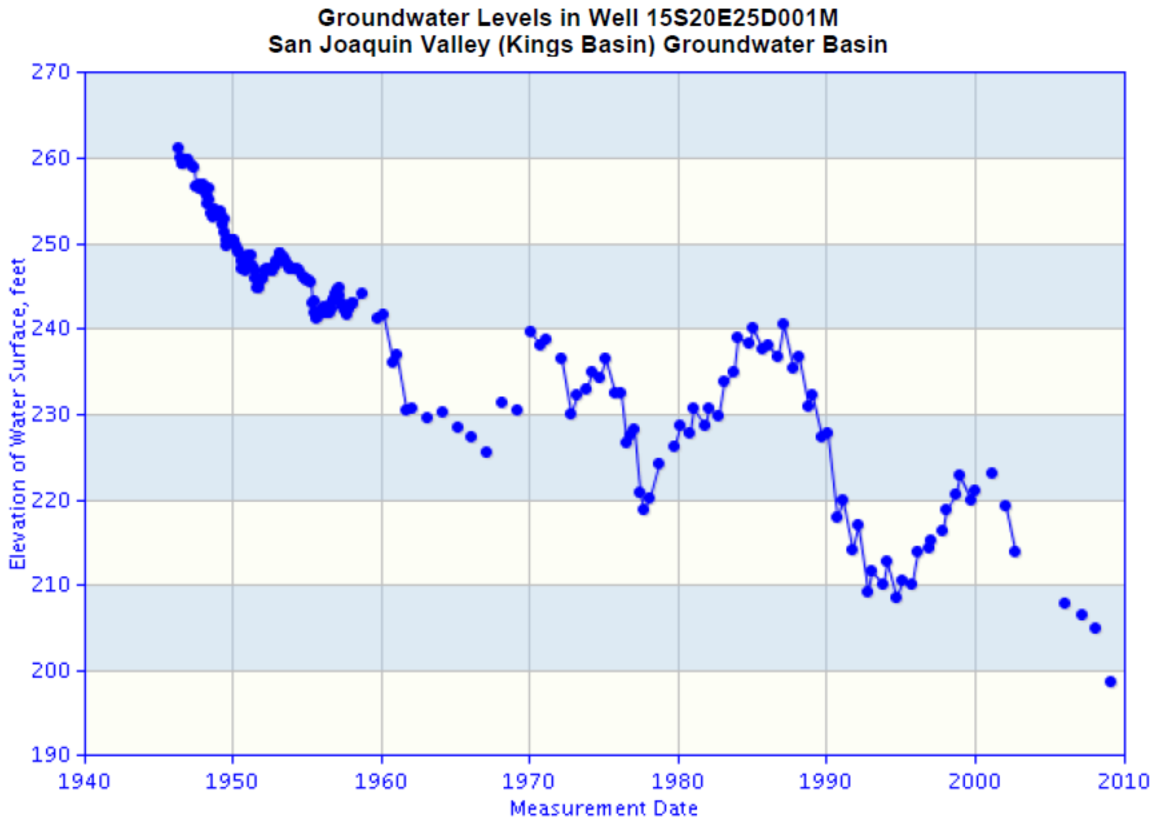

Figure 3.7-6
Rural North Water Well Hydrograph (CDWR 2011)

04/02/2014 - RFP No.: HSR13-57

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- Kings River Crossing (FB–C): Groundwater in the unconfined aquifer is likely to be encountered approximately 60 feet bgs at the northern end of this subsection, falling to approximately 90 feet bgs to the southern end of the subsection based on Figure A6 of Appendix A. Figure 3.7-7 shows a hydrograph of a well slightly east of Denver Avenue and 7th Avenue just east of the HST alignment. This well is relatively typical of the groundwater table elevation throughout Segment FB-C. The ground surface elevation is at this well is about 275 feet ASL indicating the current groundwater table is currently about 80 feet bgs at this location.

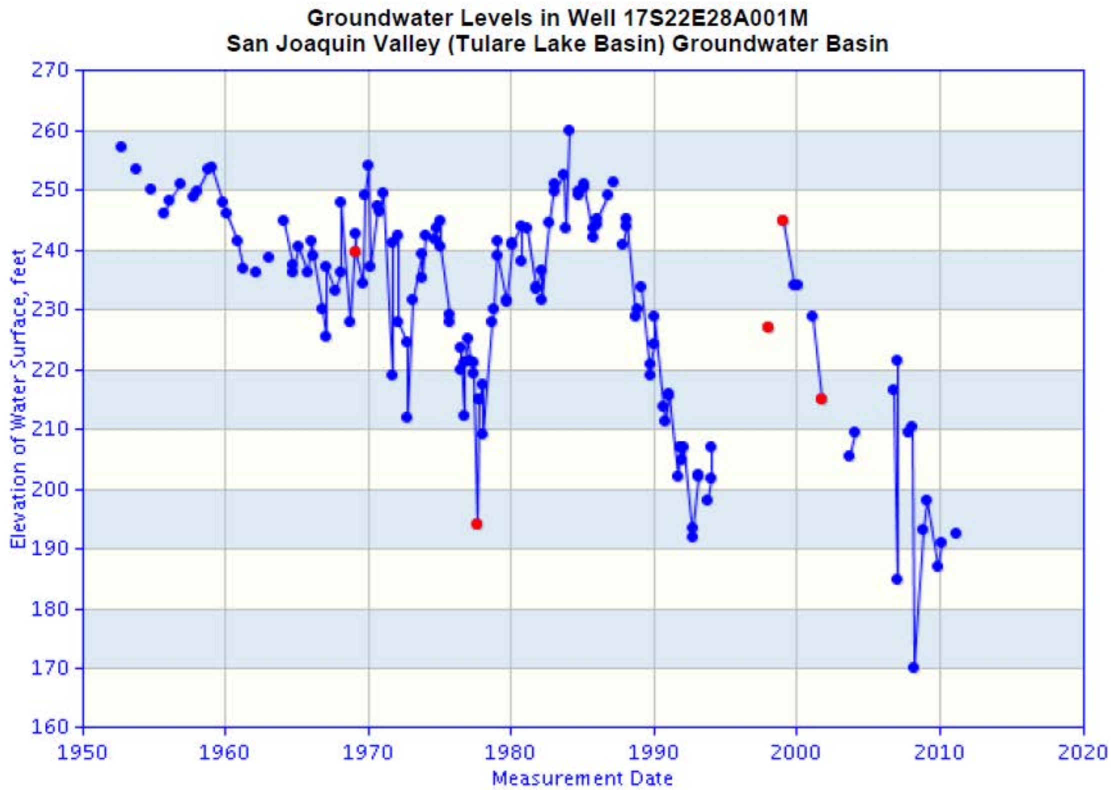

Figure 3.7-7
King River Crossing Water Well Hydrograph (CDWR 2011)

04/02/2014 - RFP No.: HSR13-57

- Hanford Station-East (FB–D): Groundwater in the unconfined aquifer is likely to be encountered approximately 90 feet bgs at the northern end of this subsection, falling to approximately 120 feet bgs at the southern end of the subsection based on Figure A6 of Appendix A. Figure 3.7-8 shows a hydrograph of a well slightly east of Fargo Avenue and 7 ½ Avenue just west of the HST alignment. This well is relatively typical of the groundwater table elevation throughout Segment FB-D. The ground surface elevation at this well is about 237 feet ASL indicating the current groundwater table is about 105 feet bgs at this location.

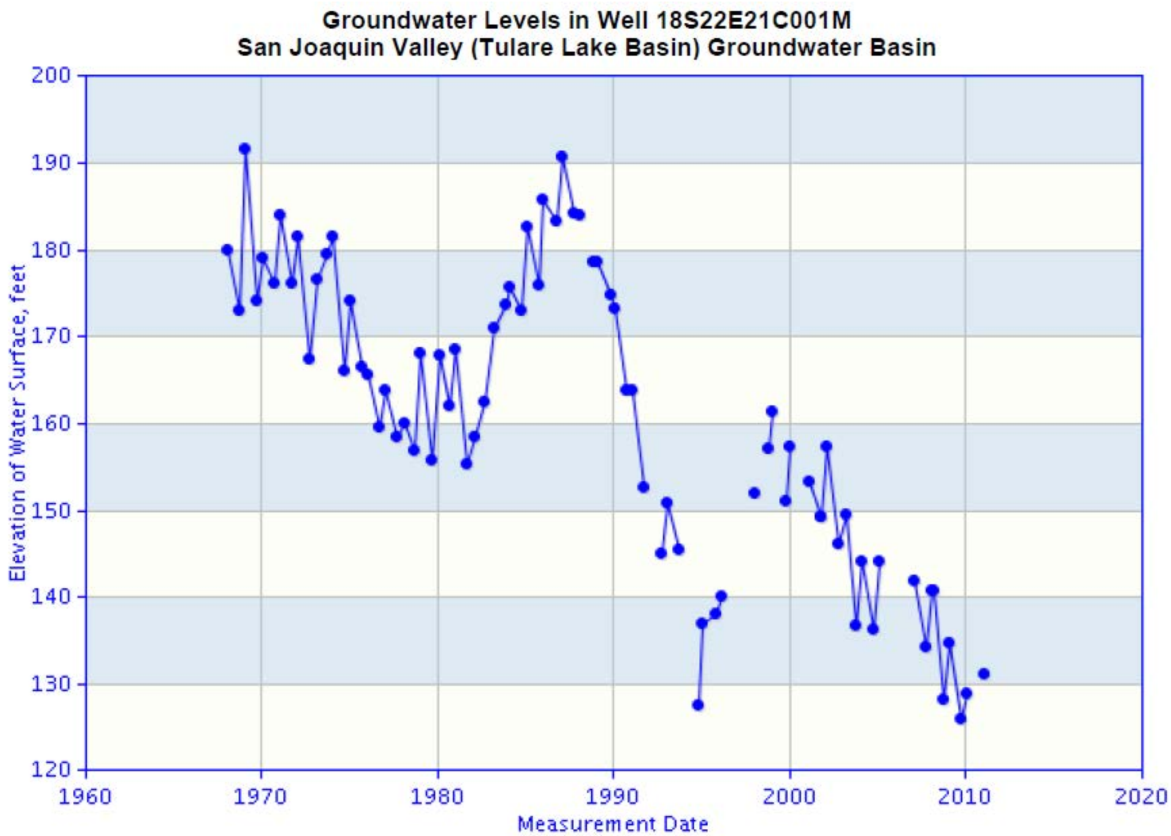

Figure 3.7-8
Hanford Station (East) Water Well Hydrograph (CDWR 2011)

- Hanford Station-West (FB–D): While there are a number of well points in the vicinity of the Hanford West Bypass that suggest current groundwater could be encountered as deep as 110 to 120 feet, there are a number of points indicating groundwater in the unconfined aquifer may possibly be encountered at 30 feet bgs at the northern end of this subsection, falling to approximately 60 feet bgs at the southern end of the subsection based on the well hydrographs shown on Figure 3.7-9 and Figure 3.7-10 respectively. However, as recently as one decade ago these wells indicate groundwater was as shallow as 20 feet bgs on the north end to less than 10 feet bgs on the south end. The well in Figure 3.7-9 is located at about Grangeville Blvd and 13th -1/2 Ave while the well in Figure 3.7-10 is located near the Lone Oak canal at about a ¼ miles east of 13th Ave and a ¼ mile south of Hume Ave. These figures show a hydrographs of wells within a quarter of a mile west of the alignment. The ground surface elevations at the wells shown on the figures below are 243 feet ASL and in 236 feet ASL, respectively.

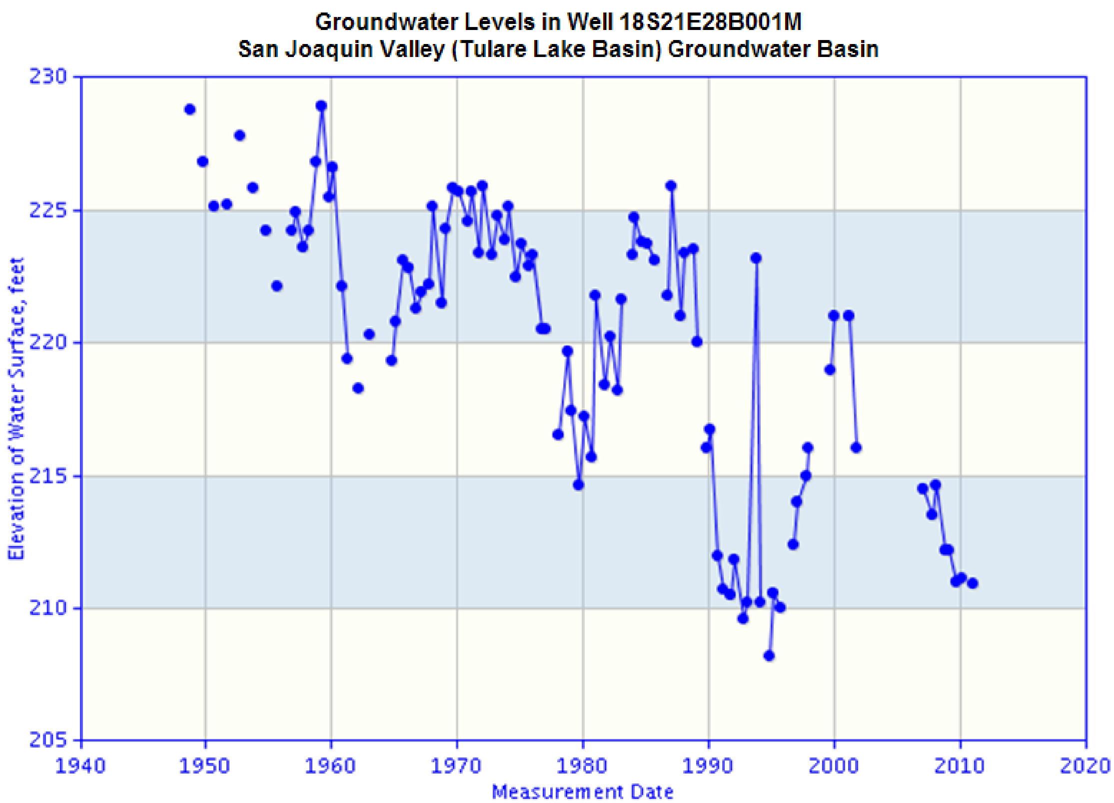

Figure 3.7-9
Hanford Station (West) Water Well Hydrograph (CDWR 2011)

04/02/2014 - RFP No.: HSR13-57

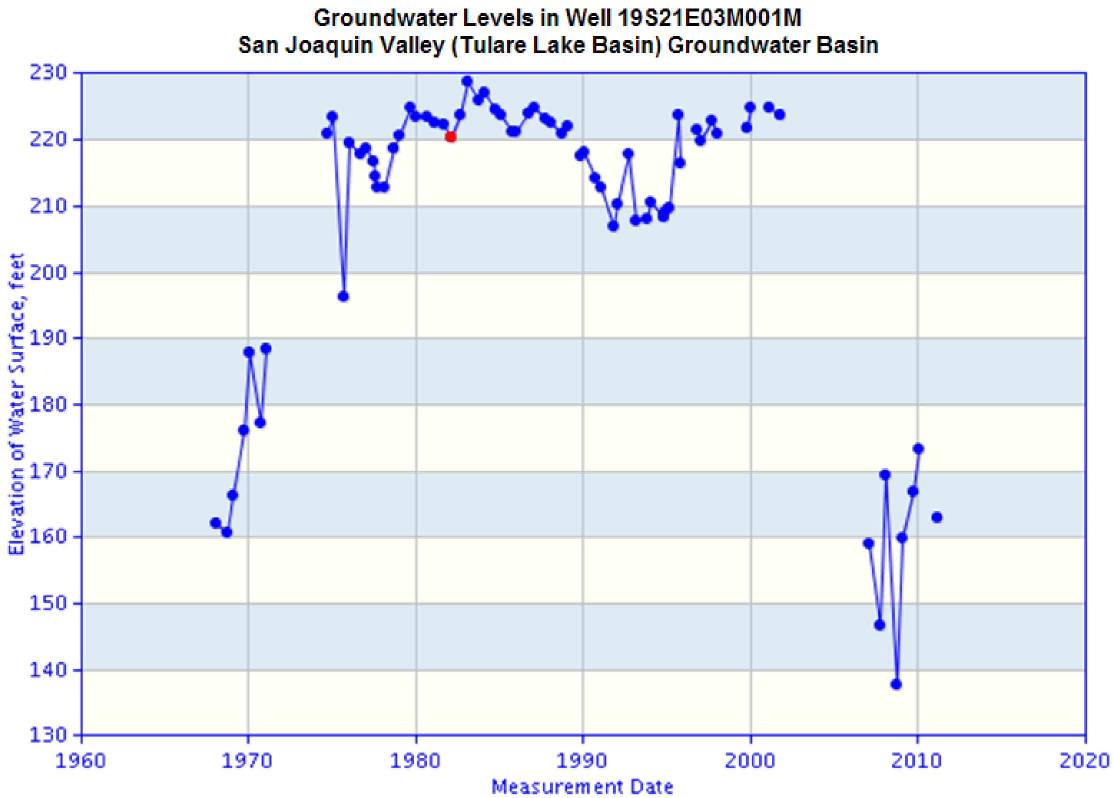

Figure 3.7-10
Hanford Station (West) Water Well Hydrograph (CDWR 2011)

04/02/2014 - RFP No.: HSR13-57

- Rural Central (FB–E): There is insufficient data on Figure A6 of Appendix A to fully describe the groundwater regime in this subsection; however, there is data for an approximate 5 mile portion of the alignment immediately north of Corcoran. Groundwater in the unconfined aquifer is shown to have been encountered approximately 140 feet bgs approximately 5 miles north of Corcoran, rising to approximately 110 feet bgs on the northern edge of Corcoran to the east of the current alignment based on Figure A6 of Appendix A. Between ½ mile south of Kansas Avenue to Hanford the current depth to groundwater is about 125 to 150 feet based on CDWR hydrographs. Figure 3.7-11 shows a hydrograph of a well at Lansing Avenue and Highway 43 east of the HST alignment (about 7 miles north of Corcoran) and is relatively typical of the groundwater table elevation fluctuations throughout Segment FB-E. The ground surface elevation is at this well is about 216 feet ASL indicating the current groundwater table is about 85 feet bgs at this location. In 2006 the groundwater table in a well on the HST alignment at Nevada Ave just north of Corcoran was 80 feet bgs.

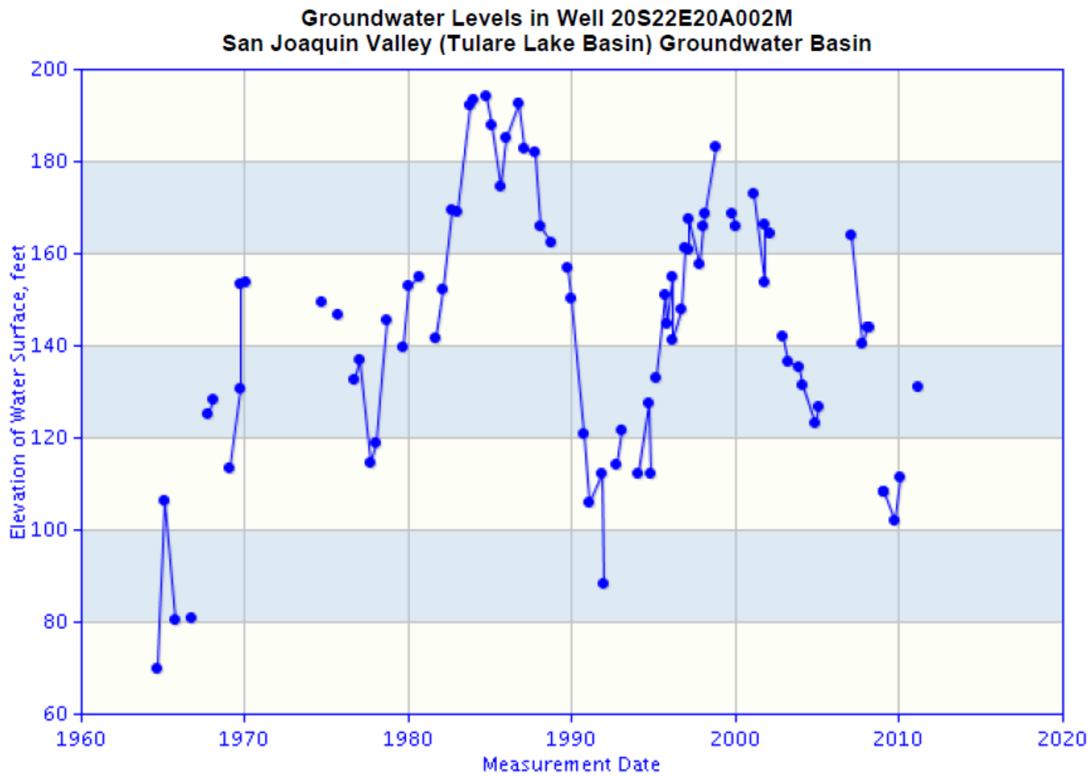

Figure 3.7-11
Rural Central Water Well Hydrograph (CDWR 2011)

04/02/2014 - RFP No.: HSR13-57

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- Tule River Crossing (FB–F): There is insufficient data on Figure A6 of Appendix A to fully describe the groundwater regime in this subsection; however, review of 1995-2000 CDWR contours of depth to groundwater in the unconfined aquifer indicate groundwater between 120 feet and 140 feet bgs, 2-4 miles east of the HST alignment at the Tule River Crossing. Figure 3.7-12 shows a hydrograph of a well at Avenue 144 just west of the HST alignment. The ground surface elevation at this well is about 205 feet ASL indicating the current groundwater table is about 45 feet bgs at this location.

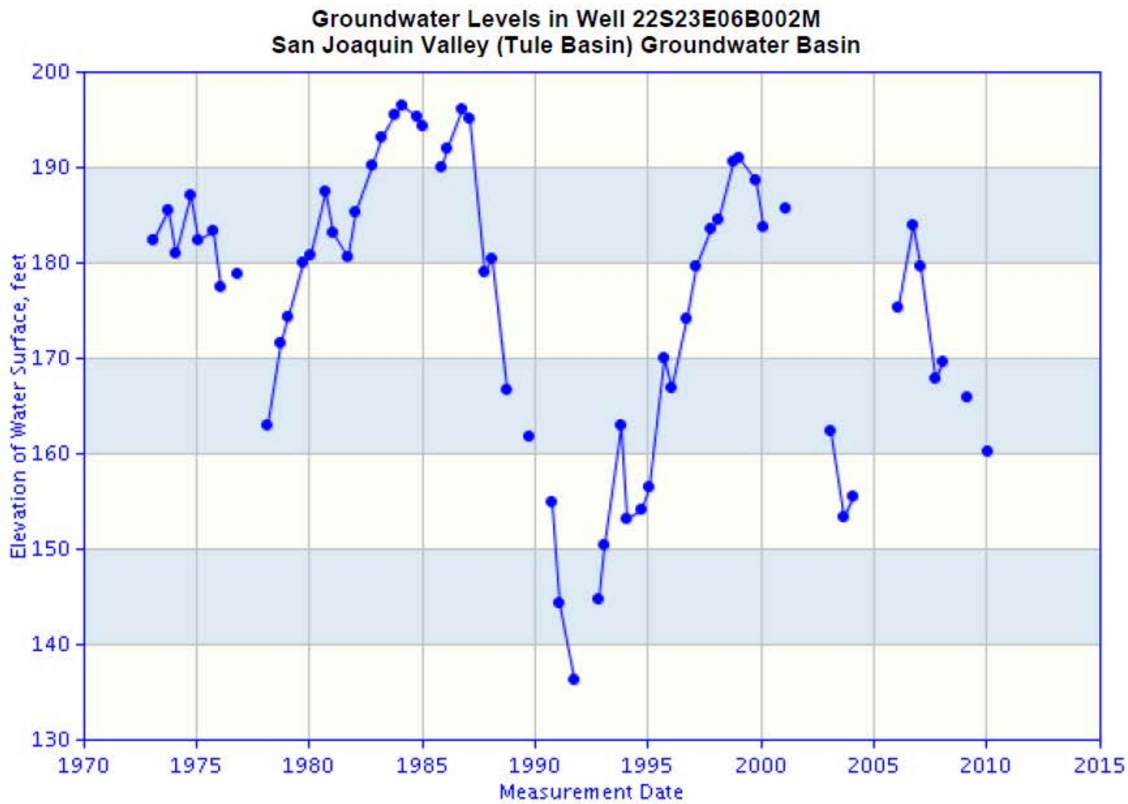

Figure 3.7-12
Tule River Crossing Water Well Hydrograph (CDWR 2011)

Subsections FB-G through FB-L

The southern reach of the study area encompasses the Kern County Groundwater Sub-Basin and the Tule Groundwater Sub-Basin (CDWR, Bulletin 118). The Kern County Groundwater Sub-Basin is bounded on the north by the Kern County line and the Tule Groundwater Sub-basin; the southeast by the granitic bedrock of the Sierra Nevada foothills and Tehachapi Mountains; and on the southwest and west by the marine sediments of the San Emigdio Mountains and Coast Ranges. Principal rivers and streams in both sub-basins include the Tule River, the Kern River, Caliente Creek, Deer Creek and Poso Creek. Average precipitation ranges from 5 inches at the sub-basin's interior to 9 to 13 inches at the sub-basin's margins to the east, south and west (see Figure 3.7-1).

The *average* water level throughout the Kern County and Tule Groundwater sub-basins is essentially unchanged from 1970 to 2000. There were, however, several fluctuations including a 15-foot drop through 1978, a 15-foot increase through 1988, and an 8-foot decrease through 1997. Net water level changes in different portions of the sub-basins were quite variable through the period 1970-2000. These changes ranged from increases of over 30 feet at the southeast valley margin and in the Lost Hills/Buttonwillow areas to decreases of over 25 and 50 feet in the Bakersfield area and McFarland/Shafter areas, respectively.

Groundwater is likely to be encountered at the following depths along the FB Section of the HST proposed alignment:

- Rural South (FB-G): Figure 3.7-4 above shows groundwater table elevations between Corcoran and Wasco from a study conducted on the groundwater conditions in the vicinity of the Pixley National Wildlife Refuge and Subsection FB-G during 1987 — a peak year for regional groundwater table levels (Quinn 2007). Ground surface elevations along the alignment between Corcoran and Allensworth range between EL 200 and 212 while groundwater contour elevations in Figure 3.7-4 range between 160 and 180. Between Allensworth and the Tulare/Kern County line the ground surface elevation rises from about EL 207 to about EL 240 at the Tulare/Kern County line while the groundwater table increases gently in elevation from 155 to 190. Thus, there is a potential for shallow groundwater in this reach of the alignment. The 1987 contours from the Pixley study shown in Figure 3.7-4 indicates that much shallower groundwater table elevations were present in 1987 ranging between 30 and 60 feet bgs.

- Rural South (FB-G): In Tulare County there is very little groundwater data available to be extrapolated from Figure A6 of Appendix A. Contours from the Spring of 2004 indicate that the unconfined aquifer is about 40 feet deep at the county line; 100 feet bgs at Allensworth and; about 130 feet bgs directly east of Alpaugh. In the spring of 2005 there is one contour midway between the Deer Creek Crossing and the Lakeland Canal Crossing that suggests the aquifer is about 160 feet bgs. Figure 3.7-13 shows a hydrograph of a well at Avenue 128 just west of the HST alignment. The ground surface elevation is at this well is about 205 feet ASL indicating the current groundwater table is about 68 feet bgs at this location.

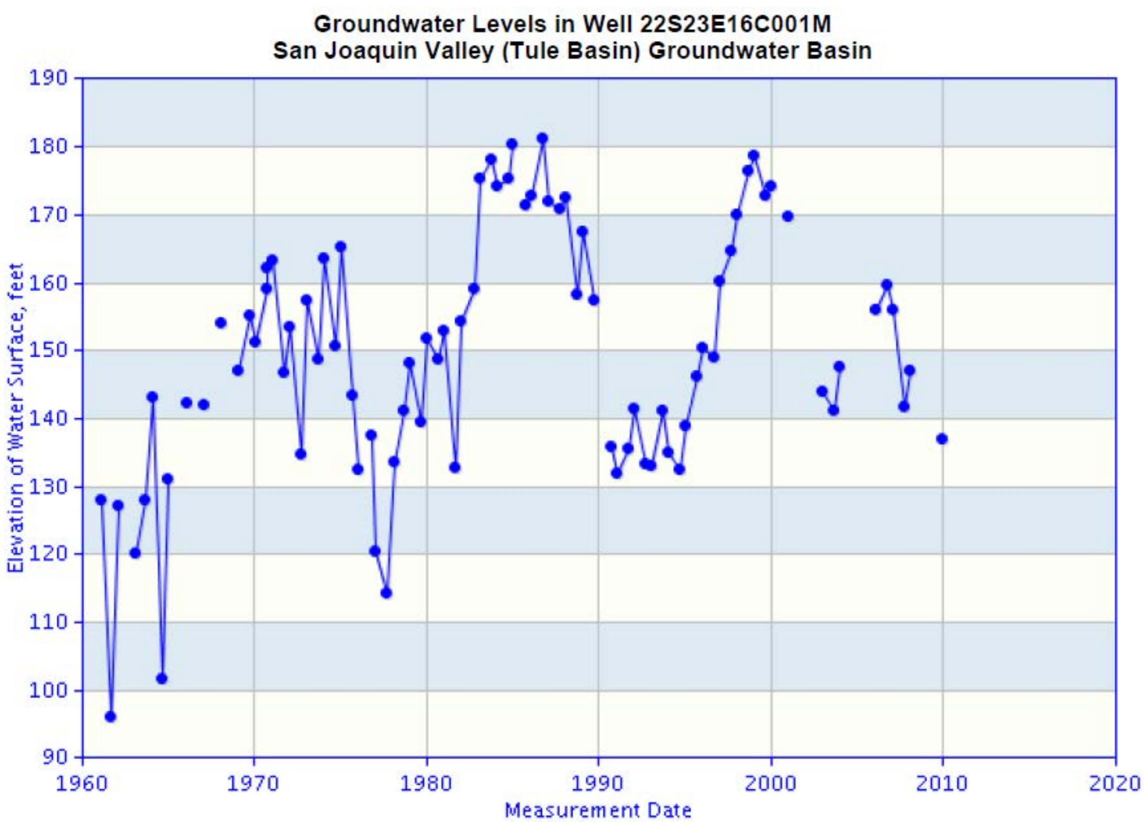

Figure 3.7-13
Rural South (N) Water Well Hydrograph (CDWR 2011)

- Rural South (FB-G): Figure 3.7-14 shows a hydrograph of a well southeast of Allensworth on Avenue 40. The ground surface elevation is at this well is about 212 feet ASL indicating the current groundwater table is about 140 feet bgs at this location. The Pixley contours show a groundwater table elevation of about 155 in 1987 at this location corresponding to a groundwater depth of 57 feet. The red dots on this graph indicated the data are not as reliable.

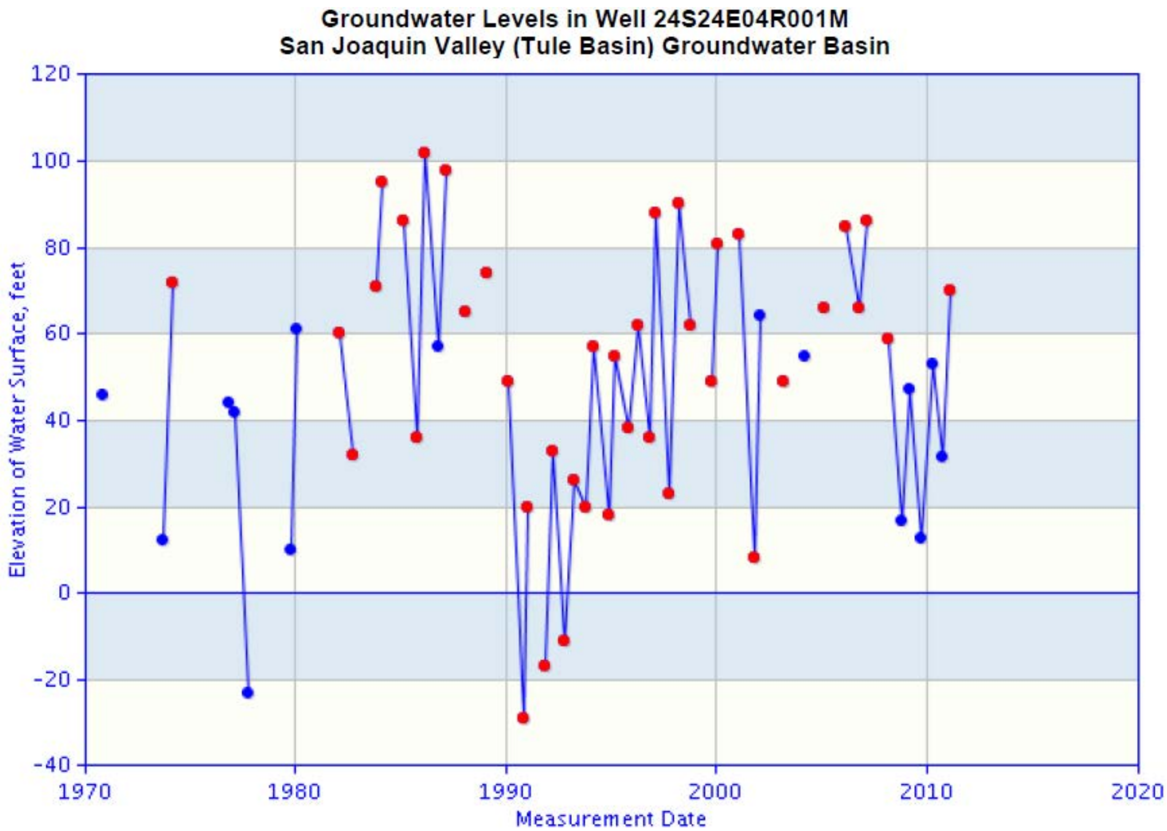

Figure 3.7-14
Rural South (M) Water Well Hydrograph (CDWR 2011)

04/02/2014 - RFP No.: HSR13-57

- Rural South (FB-G): In Kern County between Wasco and Poso Creek, groundwater in the unconfined aquifer is likely to be encountered between 200 and 260 feet bgs based on Figure A6 of Appendix A. As shown in Figure 3.7-7, the depth to the groundwater table in the vicinity of the Town of Pond varied from 130 to 230 feet bgs during the drought years of 1976 and 1978 (Holzer 1980). One well in the vicinity of pond records a groundwater table depth of on 60 feet in 1996; there were no further records for that well. At other wells the groundwater table in recent years peaked at between 100 and 130 feet bgs. At the Kern/Tulare County line, groundwater in the unconfined aquifer is likely to be encountered between 40 and 60 feet bgs. Figure 3.7-15 shows a hydrograph of a well near the Kern/Tulare County Line. The ground surface elevation is at this well is about 235.0 feet ASL indicating the groundwater table is currently about 50 feet bgs at this location.

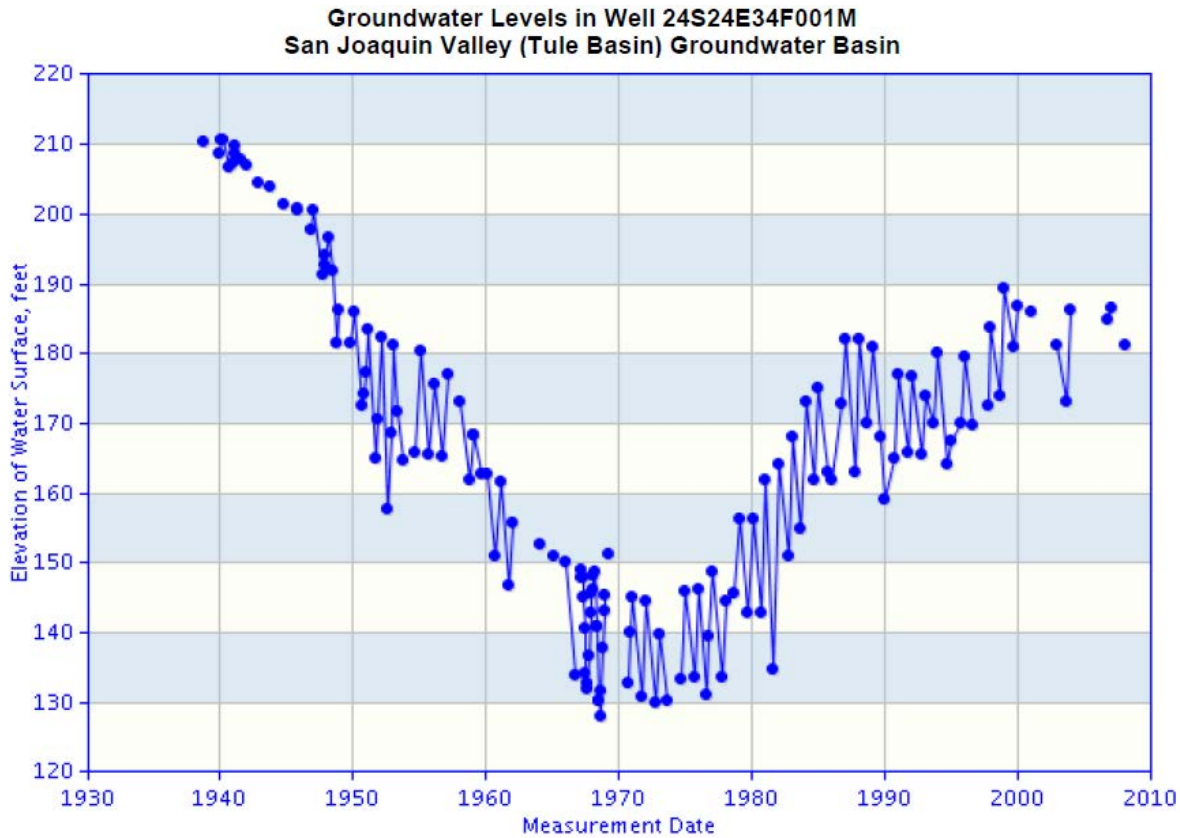

Figure 3.7-15
Rural South (S) Water Well Hydrograph (CDWR 2011)

- Wasco and Shafter (FB-H): Groundwater in the unconfined aquifer is likely to be encountered between approximately 250 to 265 feet bgs from Poso Creek to Shafter and then becomes shallower to about 150 feet south of Shafter to Hageman Road based on Figure A6 of Appendix A. Figure 3.7-16 shows a hydrograph of a well in Wasco at northwest of the intersection of 7th St and Central Avenue that is relatively typical of Segment H in the vicinity of Wasco. The ground surface elevation is at this well is about 317.5 feet ASL indicating the groundwater table is currently about 275 feet bgs at this location. Figure 3.7-17 shows a hydrograph of a well in Shafter near North Shafter Road and Fresno Road that is relatively typical of Segment H in the vicinity of Shafter. The ground surface elevation is at this well is about 355.0 feet ASL indicating the groundwater table is currently 285 feet bgs at this location.

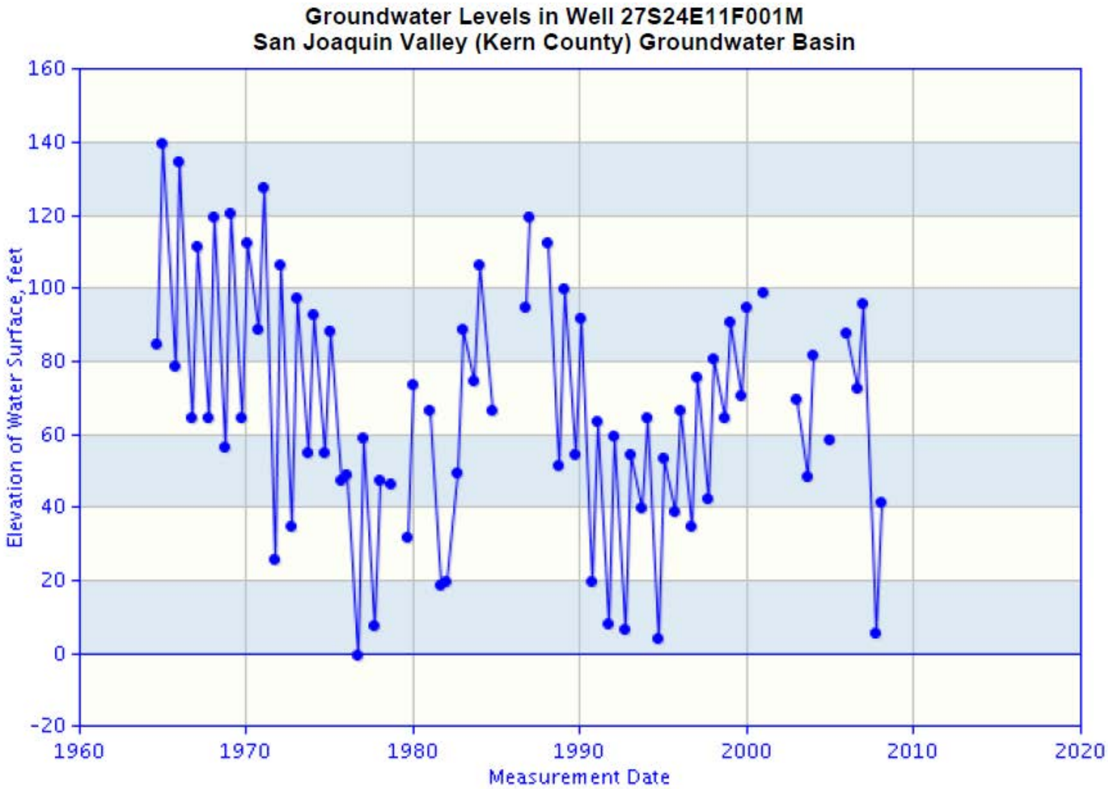

Figure 3.7-16
Wasco Water Well Hydrograph (CDWR 2011)

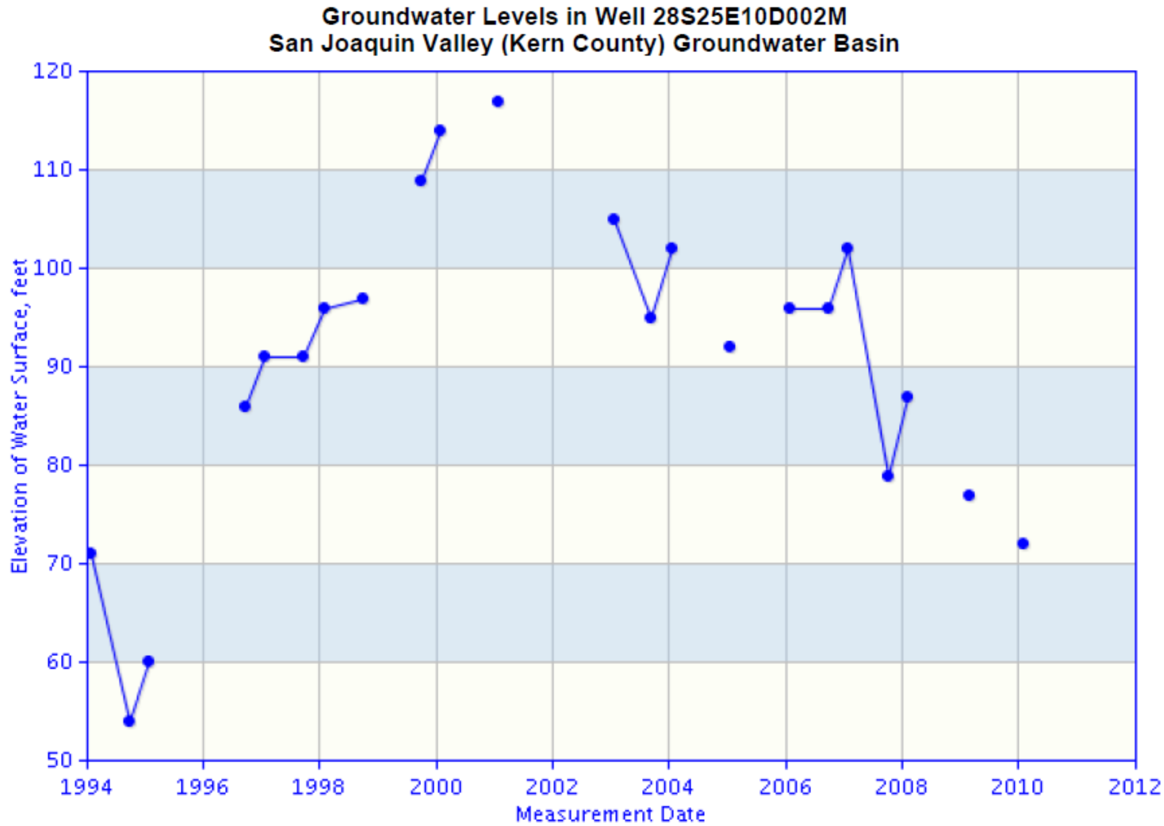

Figure 3.7-17
Shafter Water Well Hydrograph (CDWR 2011)

04/02/2014 - RFP No.: HSR13-57

- Bakersfield North (FB-J): Groundwater in the unconfined aquifer is likely to be encountered between approximately 150 to 200 feet bgs based on Figure A6 of Appendix A. Figure 3.7-18 shows a hydrograph of a well near Hageman Road near the HST alignment that is relatively typical of Segment FB-J. The ground surface elevation is at this well is about 384.5 feet ASL indicating the current depth to groundwater to be about 235 feet at this location. However, many of the points are red dots indicating that these data are less reliable.

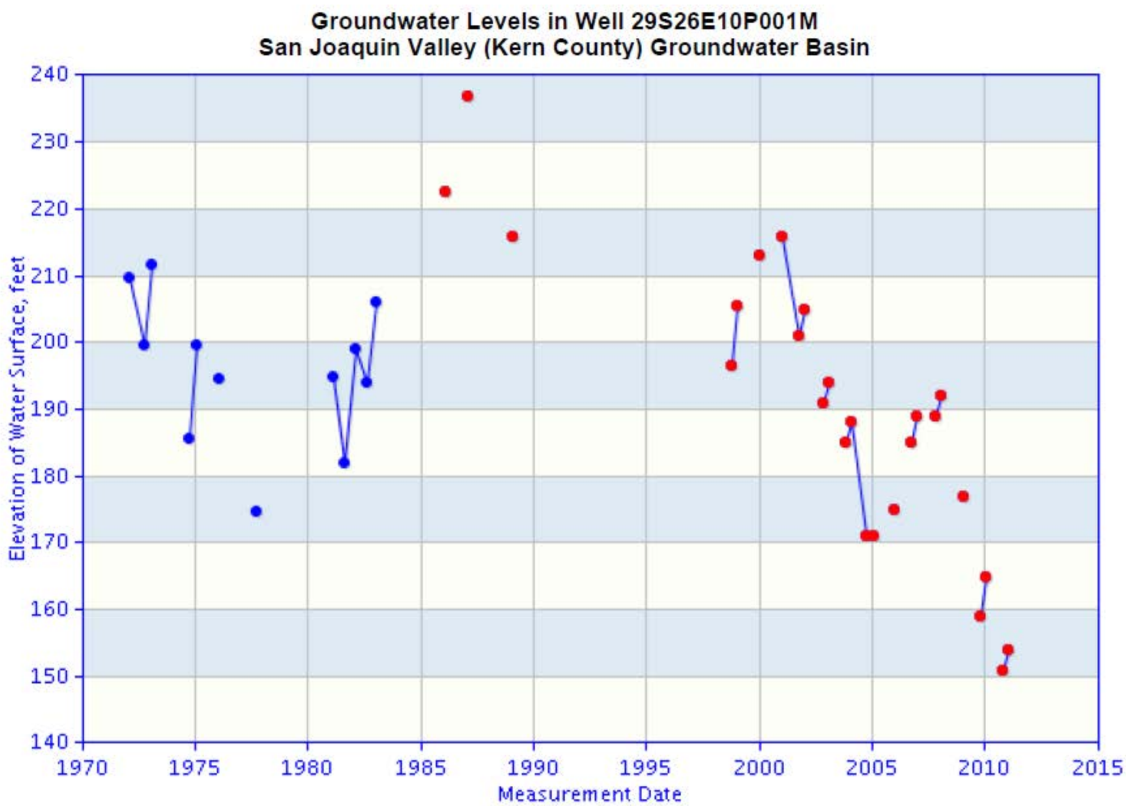

Figure 3.7-18
Bakersfield North Water Well Hydrograph (CDWR 2011)

- Kern River Crossing (FB-K): Groundwater in the unconfined aquifer is likely to be encountered between 110 feet to 160 feet bgs based on Figure A6 of Appendix A. There are several recent geotechnical studies in this segment related to the proposed Westside Parkway (Kleinfelder 2008a; Kleinfelder 2008b) and to the Mohawk Interchange Improvements (Dokken 2008) that encountered groundwater at much shallower depths. On the Westside Parkway studies, groundwater was encountered at elevations between 322 and 332 feet ASL, or about 55 to 65 feet below grade. This study was conducted between June and August of 2007. In the Mohawk Interchange Improvements report, Dokken states that groundwater was recorded by Geocon Consultants, Inc. at unusually shallow depths of between 9 and 44 feet bgs between August and September of 2006. Equally unusual was that the Kern River was flowing during those months. It was later determined that these abnormalities were attributable a discharge of over 450,000 acre-feet of water mandated by the USACE to reduce the storage capacity of Lake Isabella by two-thirds until repairs could be made to the dam. In late 2008, Dokken evaluated CDWR data from seven wells in the vicinity of the project and determined that the collective mean groundwater was at 319 feet mean sea level (MSL) (70 feet bgs) with a mean high of 365 feet MSL (35 feet bgs) and a mean low of 252 feet MSL (135 feet bgs). Figure 3.7-19 shows a hydrograph of a well near Brimhall Road and Coffee Avenue that is relatively typical of Segment FB-K. The ground surface elevation is about 385 feet ASL indicating the depth to groundwater in 2005 to be about 100 feet at this location.

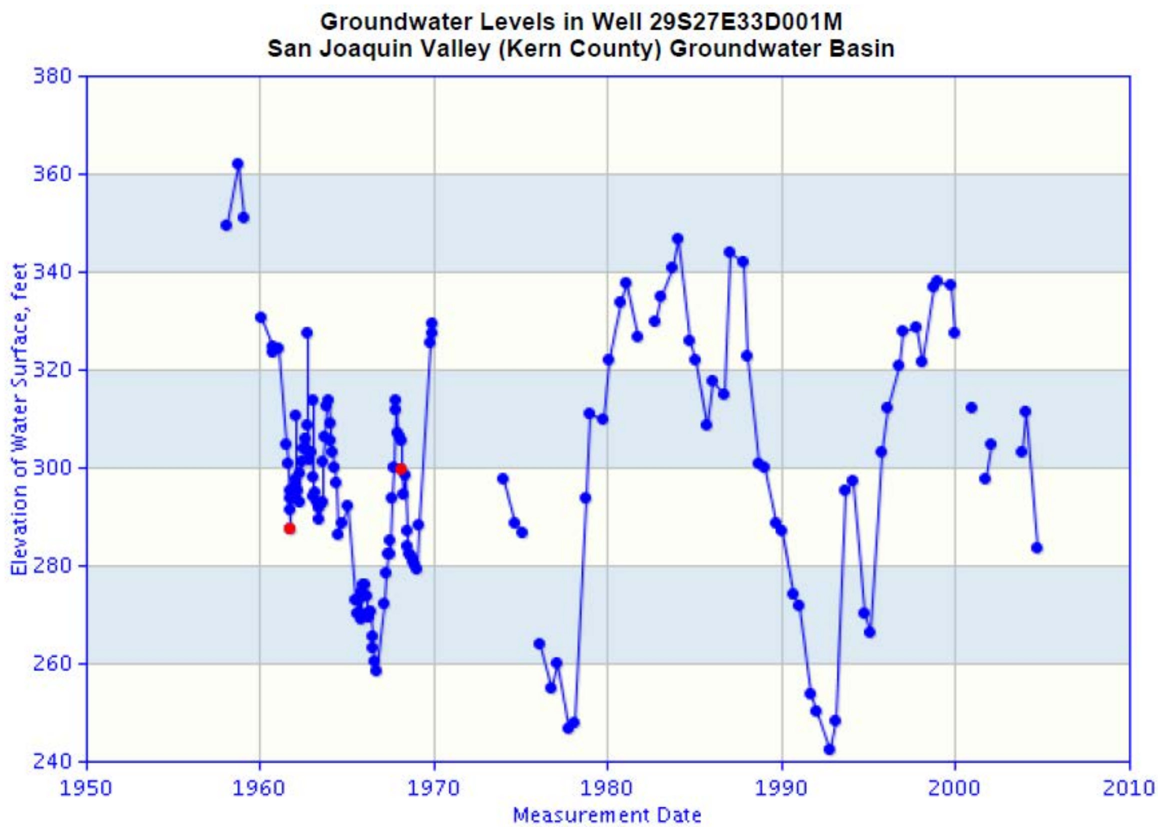

Figure 3.7-19
Kern River Crossing Water Well Hydrograph (CDWR 2011)

- Bakersfield South (FB-L): Groundwater in the unconfined aquifer between Oak Street and Union Avenue is likely to be encountered between 110 feet and 200 feet bgs, at which point the water table begins to fall such that between Union Avenue and Weedpatch Highway the

aquifer is likely to be encountered at 150 feet to 250 feet bgs. Beyond Weedpatch Highway to the end of the study area, the groundwater table falls to over 480 feet bgs. Groundwater levels in the vicinity of Edison were recorded by at 340 and 350 feet bgs in 2006; in 1991 the groundwater table levels were encountered at 290 bgs (Geomatrix 2006). Figure 3.7-20 shows a hydrograph of a well near Chester Avenue and California Avenue that is relatively typical of Segment FB- L. The ground surface elevation is about 400 feet ASL indicating that the current depth to groundwater to be 205 feet at this location.

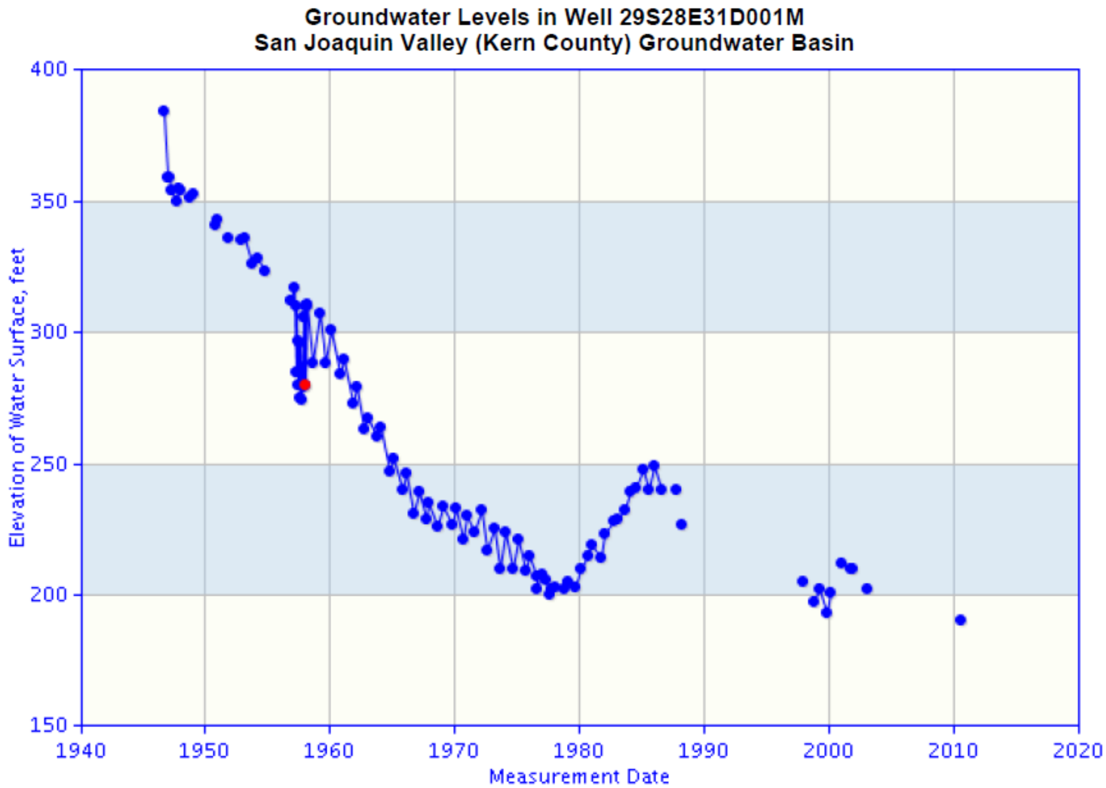

Figure 3.7-20
Bakersfield South Water Well Hydrograph (CDWR 2011)

3.7.6 Confined and Perched Groundwater

All of the groundwater levels identified above are approximate, are subject to seasonal fluctuations, and are likely more representative of mean low conditions. The published groundwater table depths are for the unconfined aquifer and take no account of localized high-level perched groundwater tables, deeper confined aquifers, or potentially artesian or sub-artesian groundwater conditions. Anecdotal evidence from direct observation suggests the groundwater table in Bakersfield can fluctuate to as high as 5 feet bgs in response to seasonal fluctuations in precipitation (Arup/drilling contractor, personal communication, 2009). Several environmental studies have shown perched groundwater conditions in the vicinity of Hanford, and the groundwater and implications are discussed in detail below.

Groundwater regimes beneath the proposed alignment are likely to be variable both seasonally and geographically. Higher groundwater levels (including seasonal flooding) are anticipated at or near the major river crossings, and laterally discontinuous local perched groundwater is associated with the more cohesive elements of the soils profiles, particularly where clay soils are noted, e.g., around Corcoran (see Appendix C).

The sediments that make up the aquifer are generally coarse grained (sands and gravels of fluvial origin); however, significant proportions of laterally discontinuous lenticular fine grained materials (clays and silts of lacustrine and marsh origin) could act as aquicludes controlling the vertical and lateral movement of groundwater if they are laterally persistent. Most fine-grained layers are not laterally persistent enough to form significant aquicludes; however, the Corcoran Clay that underlies the proposed alignment at depths ranging from about 200 to 600 feet will lead to confined and semi-confined conditions where groundwater is confined below the Corcoran Clay, as shown in Figure 3.7-21.

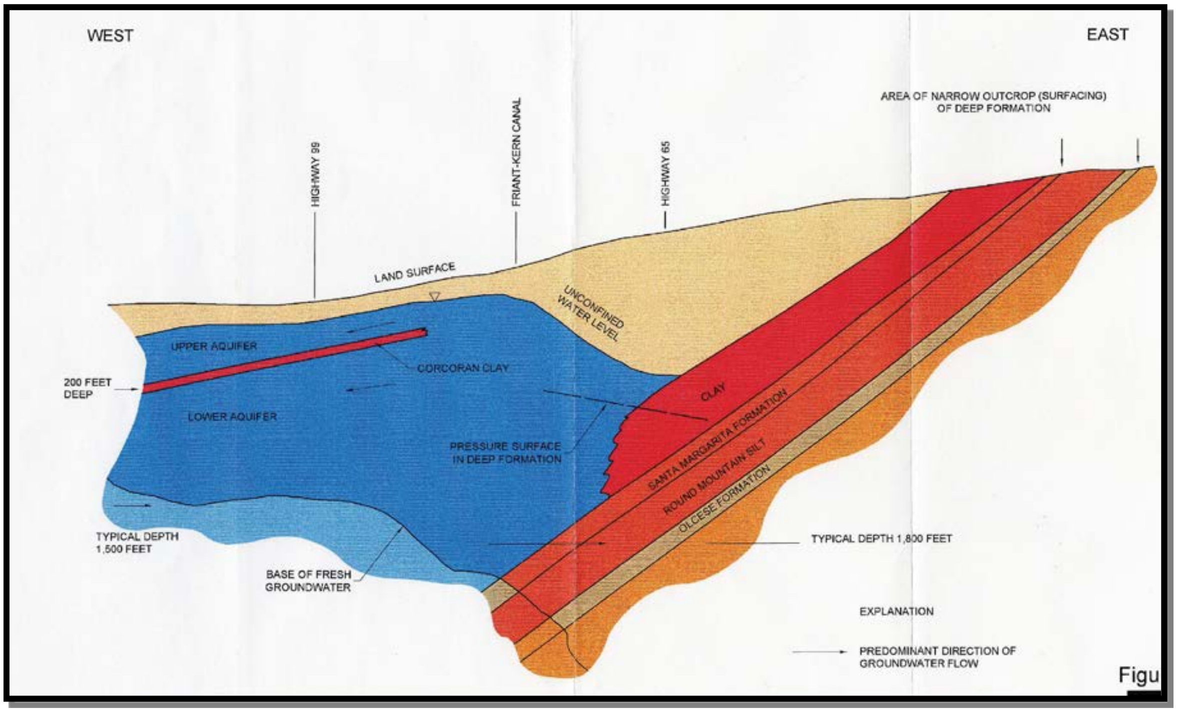

Figure 3.7-21
Tulare Lake Basin: Semi-Confined Aquifer (after Quinn 2007 and Schmidt 2001)

Annual water measurements show fluctuations as much as 60 feet over the 30-year period from variations in pumping, recharge and climate. The actual fluctuations vary considerably between sub-basins but in broad terms along the route alignment groundwater levels have declined over the last 100 years in response to pumping and reduced recharge only to recover (if sporadically) in recent years due to controls on pumping and groundwater recharge. Sources of groundwater recharge include by river and stream seepage, deep percolation of irrigation water, canal seepage, and intentional recharge areas such as Leaky Acres Groundwater Recharge Facility near Fresno and the Corcoran Irrigation District.

Hanford Area Groundwater

A below-grade option in the vicinity of Hanford-Armona Road in Hanford is under consideration. From desktop information, the groundwater conditions of the area are somewhat difficult to characterize. Several nearby environmental studies indicated perched groundwater conditions above an aquitard, which result in saturated soils from 15 to 80 feet below grade. There is likelihood that this the saturated conditions are related to leakage from irrigation canals; however, the extent of these saturated areas cannot be defined from existing data. Below the aquitard, the soil is unsaturated to approximately 120 feet below grade, where a more extensive aquifer is characterized. The existence of saturated conditions and perched groundwater in the cut is expected to be prevalent (possibly as shallow as 6 feet deep) throughout the cut, based on

04/02/2014 - RFP No.: HSR13-57

personal communications with Mr. Hugo Cavillo, District Conservationalist with the Hanford District of the Natural Resources Conservation Service on May 14, 2013 . Because the design of the depressed alignment option will be influenced by the local groundwater conditions, characterization of the groundwater table in the vicinity of the HW and HW2 alignment will be a key component of future geotechnical investigations.

3.7.7 Shallow Groundwater Impacts

Changes in the depth to groundwater through perched conditions and seasons of recharge require consideration during stability of embankments and the design of deep foundations. The potentially variable conditions may also influence drilling activities and the contractor's ability to successfully advance drilled holes. When water is encountered during drilling operations there is a greater risk of caving. To prevent caving, holes can be filled with water and drilled under a water head. If excessive water is needed to keep the head of water at or near the ground surface, a bentonite or other form of drilling slurry may be used, or casing may be utilized to advance the hole.

Drilling activities may encounter substantial groundwater infiltration in certain sections of the alignment. Drilling slurries and/or casing will likely be used throughout most sections of the alignment due to the cohesionless nature of the soils. If perched groundwater is encountered, water or drilling slurries may be used to maintain the integrity of the drill hole. This water can be collected and reused in subsequent holes. Typically, large tanks are used to keep the water until it is used on the next hole or until it can be properly tested and appropriately discharged.

Withdrawal during droughts and subsequent recharge can cause fluctuations in the groundwater level of 100 feet or more posing a hazard that must be considered during the design of foundations and slopes along the HST alignment. Current groundwater tables may not be the most critical from a design perspective; historical groundwater table levels require careful consideration.

Areas of known historical shallow and perched groundwater in the along the alignment are discussed together with liquefaction potential in Section 3.7.7 and 4.5.1 and are shown on Figure 4.5-1. Perched or free groundwater may be considerably shallower than presented in Table 3.7-4. Table 3.7-4 shows the depth to groundwater table during periods when the groundwater was relatively shallow by comparison to the 2005 groundwater table contours shown on Figure A6 of Appendix A and groundwater tables within the last two years.

Table 3.7-4
Depth to Groundwater Table (feet)

Location	Existing Grade	Period				
		1960-65	1984-88	1998- 01	2005	2009-11
Roeding Park	290	60	80	90	100	
Ventura Street	291	59	71	80	101	125
East North Avenue	287	30	45	67	65	
East Morton Avenue	289	29	26	32	52	63
Bowles	275	33	34	52	65	76
Conejo	261	36	41	59	81	90
East Davis Street	258	38	26	43	63	76
Denver Avenue	275	22	23	29	60	83
Dover Avenue	265	27	25	47	70	

04/02/2014 - RFP No.: HSR13-57

CALIFORNIA High-Speed Rail Authority

Location	Existing Grade	Period				
		1960-65	1984-88	1998- 01	2005	2009-11
Excelsior Avenue	264	24	44	68	82	
Elder Avenue	265	45	43	72	96	102
Flint Avenue	260	50	60	88	107	115
Fargo Avenue	257	67	66	95	112	125
Grangeville Blvd	250	50	70	95	125	130
Lacey Blvd	248	83	73	88	110	
Iona Avenue	240	80	80	97	144	152
Idaho Avenue	232	77	50	85	129	144
Kansas Avenue	221	121	4	71	112	141
Lansing Avenue	216	110	23	33	89	85
Nevada Avenue	212	57	32	42	102	
Corcoran	209	51	29			
Avenue 144	211	67	15	20	41	51
Tule River	209	44	19			
Avenue 128	208	63	26	29	53	70
Avenue 112	203	61	43			
Avenue 88	212	77			162	
Deer Creek	210	82	60			
Allensworth	214	74	54	134	149	149
Avenue 24	224	74	54			
K/T County Line	244	80	59	64	64	
West Cecil Way	246	61	44			
Airport Ave	262	102	47	35		82
Pond	283	143	83	108	282	
Poso Creek	307		157	202	257	
Wasco	337	197	207	237	257	
Shafter	350			232	258	278
7th Standard	344		174	160	204	
Hageman Road	365		103	110	145	
Highway 58	375		90	90	135	
Calloway Drive	382		60	80	132	
Coffee Street	388	28	41	51	103	23
Oak Street	398			140	128	
Chester Ave	400	100	150	190	200	210
Union Avenue	406			200	136	
Oswell Road	427	207		200	157	
Weedpatch Hwy	458	258		275	198	
Comanche Road	681	501		370		

3.8 Surface Soil and Rock Conditions

Soil type is a criterion used to evaluate potential impacts of development on the environment as well as evaluate potential impacts to the project from the environment. Depending upon type, some soils are susceptible to erosion and/or expansive behavior while others are more suitable for construction. Soil type mapping, emphasizing a soil's agricultural and engineering properties, has been conducted by various government agencies and universities since the 1930s. This study area uses the USDA Soil Surveys for Eastern Fresno County Area, Kings County, Tulare County, Western Part and Kern County, Northwestern Part as a source of information. These surveys typically map to a depth of 5 feet. Section 3.7 — Stratigraphy, discussed in Section 3.7, provides a description of soils below the 5 foot depth. Figures A7a through A7e of Appendix A show soil mapping for the soils likely to be crossed by the HST within the study area (USDA and NRCS 2008a, 2008b, and 2009b).

3.8.1 Subsection FB–A Fresno

Within the HST Subsection FB–A Fresno, near the proposed Fresno Station, the alignment traverses well-drained soils associated with low alluvial terraces. The San Joaquin soil series, which makes up approximately 30% of the Fresno section and is generally found between E Clinton Avenue and E Lorena Avenue, consists of silty sand (SM), silty clay (SC), lean clay (CL), and fat clay (CH) (USDA and NRCS 2008a). The soil is 0.5-1.0% organic matter near the surface and 0-0.5% organic matter below 16 inches. A hardpan is generally found at a depth of 12 to 48 inches and is between 4 and 17 inches thick. Between E Clinton Avenue and E Lorena Avenue, the Greenfield, Delhi, and Hanford soil series are also found to a lesser extent. These series are similar to the San Joaquin series, but consist mainly of silty sand; a hardpan layer is generally not present except in areas of the Greenfield series.

The Hesperia soil series, which makes up approximately 27% of the Fresno section and is generally found between E Church Avenue and E Central Avenue, consists of silty sand, silt (ML), and lean clay (USDA and NRCS 2008a). The soil is 0.5-1.0% organic matter near the surface and 0-0.5% organic matter below 16 inches. A hardpan is generally not present. Other soil series present include the Hanford and Madera series, which are similar to the Hesperia series. However, the Madera series, which is found between E Lorena Avenue and E Church Avenue, has a clayey layer between 20 to 33 inches and a hardpan at a depth of 20 to 40 inches.

Figure A7a of Appendix A shows the distribution of these soils along the alignment in this subsection.

3.8.2 Subsection FB–B Rural North

HST Subsection FB–B Rural North crosses the Hanford-Delhi-Hesperia Association from E Central Avenue to E Davis Street. In this area, surface soil type alternatives vary frequently between the three soil series, although they do have similar properties. In general, this association consists of deep, well-drained sandy soils modified partly by wind (USDA and NRCS 2008a). Soil types include sand (SP-SM), silty sand, silt, and lean clay. In many areas, the silt and lean clay are found below a depth of 40 inches, although silt can be found at the surface and sand can be found below 40 inches. The soil is 0.5–1.0% organic matter near the surface and 0–0.5% organic matter below 16 inches. Hardpan layers are not present in this association.

The El Peco soil series is found from E Davis Street to E Barrett Avenue. This series consists of silty sand to a depth of approximately 23 inches, followed by a hardpan up to 3 inches thick between 23 and 33 inches, and then lean clay below 33 inches (USDA and NRCS 2008a). The soil is 0.5-1.0% organic matter near the surface and 0-0.5% organic matter below 10 inches.

Along the HW alignment, the Pachappa soil series is found from E Barrett Avenue to E Harlan Avenue. This series consists of silt and lean clay with no hardpan present. The soil is 0.5-1.0% organic matter near the surface and 0-0.5% organic matter below 4 inches.

Figure A7a and A7b of Appendix A shows the distribution of these soils along the alignment in this subsection.

3.8.3 Subsection FB–C Kings River Crossing

HST Subsection FB–C Kings River Crossing traverses four soil series made up of deep and very deep soils of recent alluvial fans and flood plains (USDA and NRCS 2009a). Along the HW alignment, the Pachappa soil series is found from the subsection boundary to the Cole Slough. This series consists of silt and lean clay with no hardpan present. The soil is 0.5-1.0% organic matter near the surface and 0-0.5% organic matter below 4 inches. Between the Cole Slough and the Kings River, the Grangeville soil series is found. This series consists of silty sand and silt. The soil is 1.0-6.0% organic matter near the surface and 0.5-1.0% organic matter below 8 inches.

The Kimberlina soil series is found from the Kings River to Cairo Avenue. This series consists of silty sand. The soil is 0.5-1.0% organic matter near the surface and 0-0.5% organic matter below 8 inches. The Nord soil series is found from Cairo Avenue to Dover Avenue. This soil is a combination of silt and silty sand with some lean clay and clayey sand below 18 inches. The soil is 1.0-2.0% organic matter near the surface and 0.5% organic matter below 8 inches. South of Dover Avenue, the H alignment traverses the Kimberlina series to the end of the subsection at Fargo Avenue.

The HW alignment crosses over the Grangeville soil series between E. Harlan and Kings River. South of the Kings River, this alignment predominantly traverses the Nord series.

Figure A7b of Appendix A shows the distribution of these soils along the alignment in this subsection.

3.8.4 Subsection FB–D Hanford Station

HST Subsection FB–D Hanford Station H alignment crosses deep and very deep soils of recent alluvial fans and flood plains (USDA and NRCS 2009a). Over 60% of these soils, from Fargo Avenue to State Route 198, belong to the Kimberlina soil series and are silty sands that have little organic matter (0.5-1.0%) and no cemented layers. The remaining 40%, located between SR 198 and Hanford Armona Road, belongs to the El Peco soil series. This soil consists of lean clay and silt with little organic matter (0.5-1.0%) and no cemented layers. These soils have high salinity content.

The HW alignment passes over the Nord soil series. This soil is a combination of silt and silty sand with some lean clay and clayey sand below 18 inches. The soil is 1.0-2.0% organic matter near the surface and 0.5% organic matter below 8 inches.

Figure A7b of Appendix A shows the distribution of these soils along the alignment in this subsection.

3.8.5 Subsection FB–E Rural Central

HST Subsection FB–E Rural Central runs from Hanford Armona Road to Avenue 144. Along the H alignment from Hanford Armona Road to Kansas Avenue, the soils are very deep, nearly level and made of recent alluvial fans and flood plains (USDA and NRCS 2009a). The dominant soil series are the Kimberlina soil series. These soils consist mainly of silty sand that have little

organic matter (0.5-1.0%) and no cemented layers. Other minor soil series are the Cajon, Lakeside, Garces, and Corona soil series. These soils consist of silty sand, silt, and lean clay. They have organic matter contents that range from 0.5-2.0% and no cemented layers. From Kansas Avenue to Avenue 144, the soils are saline-alkali, have a perched water table, and are in basins and on low alluvial fans, alluvial plains, flood plains, and basin rims. The major soil series is the Lakeside series that consists of silt, lean clay, and fat clay. The soil is 1.0-2.0% organic matter near the surface and 0.5% organic matter below 17 inches. Other minor series are the Cajon, Garces, Goldberg, Gambogy, and Grangeville series. These series are mostly silt and lean clay with occasional areas of silty sand. The organic matter is generally 1.0-2.0% near the surface and 0.5% with depth although some areas have organic matter contents up to 6.0% near the surface. There are no cemented layers in this area.

The HW alignment traverses the Nord series to Hume Avenue and then the Corona series to Houston Avenue. The Corona soil series is found from Dover Avenue to Excelsior Avenue. This series consists of silt and lean clay. The soil is 1.0-2.0% organic matter near the surface and 0.5-1.0% organic matter below 25 inches. The Kimberlina and, intermittently, the Nord series are found again from Houston Avenue to Kansas Avenue. South of Kansas soils traversed by the HW alignment are the same as those traversed by the H alignment.

Figures A7b and A7c of Appendix A shows the distribution of these soils along the alignment in this subsection.

3.8.6 Subsection FB–F Tule River Crossing

HST Subsection FB–F Tule River Crossing crosses very deep, nearly level soils in basins and on flood plains and basin rims. The segment consists entirely of the Gambogy soil series, which is silt and lean clay with some silty sand below 19 inches (USDA and NRCS 2009b). There are no cemented layers. The soil has 1.0–3.0% organic matter to a depth of 47 inches, below which the soil is 0.5–1.0% organic matter.

Figure A7c of Appendix A shows the distribution of these soils along the alignment in this subsection.

3.8.7 Subsection FB-G Rural South

The Rural South section is part of the Valley Terrain and is designated as Subsection FB-G. This section extends from Avenue 128 to Phillips Road and is 29.2 miles long. FB-G begins at Avenue 128, approximately 6.25 miles south of Corcoran, and ends at Phillips Road, approximately 1 mile north of Wasco. The majority of the surface soil is Fat Clay (CH), Lean Clay (CL), and Silt (ML). The permeability is slow to moderately rapid, with values ranging from 0.06 to 2 in/hr ($4x10^{-5}$ to $1x10^{-3}$ cm/s). Below 3.5 feet there are areas of Silty Sand (SM) where the permeability is approximately permeability of 20 in/hr ($1x10^{-2}$ cm/s). There are perched water tables in this area at a depth of 2.5 to 6 feet.

In Tulare County, the HST FB-G alignment crosses Gambogy-Biggriz soil associations, which consist of mixed alluvium derived mainly from granitic rock sources (USDA 2007). These soils are typically very deep, poorly to somewhat poorly drained, and have high steel and moderate concrete corrosivity potential. The shrink-swell potential is considered moderate. Within the vicinity of the Taylor Canal, the HST FB-G alignment traverses Gepford-Houser-Armona soil associations, which consist of very deep, somewhat poorly and poorly drained soils that formed in alluvium derived from granitic sources.

A high water table is present in the Gepford and Armona soils. Areas with these soils are considered to be artificially drained due to protection from flooding and pumping from the water table. In the area near the Town of Alpaugh, the HST FB-G alignment traverses Nahrub-Lethent-

Posochanet soil associations, which are very deep, somewhat poorly and moderately well drained soils. These soils form in mixed alluvium on basin rims, fan remnants and fan skirts. They are considered to have very slow to slow permeability.

Near Allensworth, the HST FB-G alignment crosses Garech-Atesh-Kimberlina soil associations, which extend to the southern limit of Tulare County. These soils are considered moderately well to well drained and formed in alluvium derived from granitic sources and where native soils were reclaimed by farming practices. A duripan exists which could be ripped and/or shattered to improve permeability, available water capacity and internal drainage.

In Kern County, the HST FB-G traverses soils associated with alluvial plains, basin rims, and floodplains of the eastern part of the SJV (USDA 1988). From the Tulare/Kern county line to north of Wasco, these soils include the following soil associations with a brief description provided of each:

- Garces-Panoche: Deep, nearly level, well drained silt loam and clay loam.
- Kimberlina-Wasco: Deep, nearly level, well drained, fine sandy loam and sandy loam.
- McFarland: Deep, nearly level, well drained loam.
- Milham: Deep, nearly level, well drained sandy loam.

A review of the Soil Survey of Kern County, Northwestern Part indicates the southern portion of the Rural South section is made of deep, nearly level soils of alluvial fans and floodplains. The majority of the surface soil is Silt (ML), Lean Clay (CL), and Silty Sand (SM). In most areas, the permeability is moderately slow to rapid, with values ranging from 0.2 to 6 in/hr ($1x10^{-4}$ to $4x10^{-3}$ cm/s). However, in areas that have more Lean Clay (CL), the permeability may slow to a value of 0.06 in/hr ($4x10^{-5}$ cm/s).

This information is in agreement with the Geologic Map of California-Fresno Sheet and Bakersfield Sheet. According to the Fresno Sheet map, the northern portion of the Rural South section is Quaternary lake deposits, consisting of clay, silt and fine sand of lakebeds. According to the Bakersfield Sheet map, the central portion of the Rural South section is recent basin deposits consisting of sediments deposited during flood stages of major streams in the area between natural stream levees and fans. The southern portion is Quaternary alluvial fan deposits consisting of sediments deposited from streams emerging from highlands surrounding the SJV.

Figures A7c, A7d and A7e of Appendix A shows the distribution of these soils along the alignment in this subsection.

3.8.8 Subsection FB-H Wasco and Shafter

The Wasco and Shafter section is part of the valley terrain and is designated as Subsection FB-H. FB-H extends from Phillips Road to Hageman Road and is 19.9 miles long. The FB-H alignment begins at Phillips Road, approximately 1 mile north of Wasco, and ends at Hageman Road, on the northwestern outskirts of Bakersfield. The HST FB-H alignment traverses soils associated with alluvial plains, basin rims, and floodplains of the eastern part of the SJV (USDA 2008b). These soils include the following soil associations with a brief description provided of each:

- Kimberlina-Wasco: Deep, nearly level, well drained, fine sandy loam and sandy loam.
- Milham: Deep, nearly level, well drained, sandy loam.

A review of the Soil Survey of Kern County, Northwestern Part indicates the Bakersfield North section is made of deep, nearly level soils of alluvial fans and floodplains. The majority of the surface soil is Silty Sand (SM) with layers of Lean Clay (CL) and Silt (ML) found below 10 inches. In most areas, the permeability is moderately slow to rapid, with values ranging from 0.2 to 6 in/hr ($1x10^{-4}$ to $4x10^{-3}$ cm/s).

These soils descriptions are in agreement with the Geologic Map of California-Bakersfield Sheet. According to the map, the Bakersfield North section is Quaternary alluvial fan deposits consisting of sediments deposited from streams emerging from the high lands surrounding the Great Valley. The southern part of the section, south of Shafter, consists locally of Pleistocene nonmarine sedimentary deposits, consisting of older alluvium in the form of fan and terrace deposits (of the Kern River Gravel).

Figure A7e of Appendix A shows the distribution of these soils along the alignment in this subsection.

3.8.9 Segments FB-J, FB-K and FB-L Bakersfield

The Bakersfield sections are designated as Subsection FB-J, FB-K and FB-L. The total length of these sections combined is 18.7 miles. The sections begin at Hageman Road, at the northeastern outskirts of Bakersfield, and end just east of Comanche Drive, at the eastern outskirts of Edison.

A review of the Soil Survey of Kern County, Northwestern Part indicates that the western portion the Bakersfield section (approximately 9 miles) is made of deep, nearly level soils of alluvial fans and floodplains. The majority of the surface soil is Silty Sand (SM) with small areas of Lean Clay (CL) and Silt (ML). Lean Clay layers are more common below a depth of 10 inches. In most areas, the permeability is moderately slow to rapid, with values ranging from 0.2 to 6 in/hr ($1x10^{-4}$ to $4x10^{-3}$ cm/s). However, there are some areas of Poorly Graded Sand with Silt (SP-SM) where the permeability may be very rapid, with a value of 20 in/hr ($1x10^{-2}$ cm/s).

The portion of the Bakersfield section east of Washington Street (approximately 8.3 miles) consists of deep, nearly level to hilly soils on alluvial fans, alluvial plains, and terraces. The HST FB-J, K and L alignments traverse the Delano-Chanac series, which formed in alluvium derived of granitic rock and the Pancho-Milham-Kimberlina. The surface soils are Silty Sand (SM), Lean Clay (CL), and Silt (ML). Permeability is moderately slow to rapid, with values ranging from 0.2 to 6 in/hr ($1x10^{-4}$ to $4x10^{-3}$ cm/s).

This information is in agreement with the Geologic Map of California-Bakersfield Sheet. According to the map, the western portion of the Bakersfield section is Quaternary alluvial fan deposits, consisting of sediments deposited from streams emerging from high lands surrounding the SJV. The portion east of Bakersfield is Pleistocene nonmarine sedimentary deposits, consisting of older alluvium in the form of fan and terrace deposits of the Kern River Gravel.

Figure A7e of Appendix A shows the distribution of these soils along the alignment in this subsection.

3.9 Stratigraphy

Stratigraphy refers to the soil below a depth of 5 feet. Section 3.8 describes soils above this level. The information in this section comes from Caltrans logs of test borings for roadways in the area dating from 1953 to 1997 and Town and County Planning Records. The quality of the data is variable based on logging methods, age, and level of detail. The available data shows that the stratigraphy of the various segments of the alignment from FB is similar; however, there are differences that are described in the following subsections.

The locations of the historical boreholes in the vicinity of the study area are shown on Figures A8a through A8e Appendix Aof Appendix A. Cross-sections of selected historical boreholes are shown on Figures A9a through A17b.

3.9.1 Subsection FB-A Fresno

Historical exploratory holes logs are available from Caltrans for the Fresno subsection, however no city reports were available in the vicinity of the proposed alignment. The majority of the Caltrans log of test borings were associated with the construction of or subsequent upgrades to Highway 99 and as such were located at least 1,500 feet away from the proposed alignment. At three locations, (I99/West Clinton Avenue, I99/I44 and I99/E North Avenue), the Caltrans exploratory holes crossed the proposed alignment and these exploratory holes were associated with highways that run perpendicular to Highway 99 or because the proposed alignment curves to the south as it leaves Fresno. Only the holes that cross the alignment have been used in the assessment of the stratigraphy of Subsection FB-A, Fresno.

At the far north end of the subsection the proposed alignment and the junction of I-99 and West Clinton Avenue are around 200 feet apart. Two sets of historical exploratory holes are associated with this junction, these holes were drilled by Caltrans in 1953 and 1990 as part of the construction or upgrade of Highway 99. The groups of exploratory holes are associated with Caltrans structures that run parallel to or cross the proposed alignment (from northeast to southwest). The stratigraphy discussed below is based primarily on the exploratory holes FBA0735h to FBA0737h as these holes are more recent. The stratigraphies described in the 1953 holes show a similarly variable sequence and are included on the geological cross section for comparison.

Following a review of the Caltrans Log of Test Borings for the junction of I-99 and West Clinton Avenue crossing the general stratigraphy can be described as follows:

- GL to 20 feet bgs (EL: 295 to 275 feet ASL) — Alternating beds of loose to very dense poorly graded sand and silty sand (standard penetration test [SPT] N 4–55) including possible hard pan at shallow depth.
- 20–26 feet bgs (EL: 275 to 269 feet ASL) – Beds of very dense silt (SPT N 91–200).
- 26–35 feet bgs (EL: 269 to 260 feet ASL) – Beds of dense poorly graded sand (SPT N 30–46).
- 35–43 feet bgs (EL: 269 to 260 feet ASL) – Very dense silt (SPT N 94–200).
- 43–85 feet bgs (EL: 260 to 210 feet ASL) — Alternating beds of dense to very dense poorly graded sand, silt, elastic silt, low plasticity silty clay and silty sand (SPT N 46–200).
- Groundwater was not recorded.

These deposits are thought to be of fluvial origin. Figure A9a presented of Appendix A shows the geological cross section for the exploratory holes discussed above.

Highway 41 crosses the proposed alignment and one set of historical exploratory holes (comprising 11 bores), drilled by Caltrans in 1963 as part of the construction or upgrade of Highway 99, have been used in this assessment of the ground conditions. The exploratory holes are associated with Caltrans structures that cross the proposed alignment (from northeast to southwest). The stratigraphy discussed below is based on exploratory holes up to 1,000 feet on either side of the proposed alignment. Following a review of the Caltrans Log of Test Borings for the intersection of Highway 41 and the proposed alignment, the general stratigraphy can be described as follows:

- GL to 15 feet bgs (EL: 285 to 270 feet ASL) — Alternating beds of loose to very dense poorly graded sand, silty sand and silt (SPT N 4–100) including possible hard pan at shallow depth.

- 15–25 feet bgs (EL: 270 to 260 feet ASL) – Beds of medium dense to very dense silt (SPT N 16–150).
- 25–45 feet bgs (EL: 260 to 240 feet ASL) – Alternating beds of dense to very dense poorly graded sand, silty sand, silt and poorly graded sand with silt (SPT N 31–90).
- 45–60 feet bgs (EL: 240 to 225 feet ASL) — Alternating beds of dense to very dense poorly graded silty sand, silt and low plasticity silty clay (SPT N 27–170).
- Groundwater was not recorded.

These deposits are thought to be of fluvial origin. Figure A9b presented of Appendix A shows the geological cross section for the exploratory holes discussed above.

In the areas where I-99 and East North Avenue cross the alignment, one set of historical exploratory holes (comprising five bores), excavated by Caltrans in 1959 as part of the construction or upgrade of Highway 99 have been used in this assessment of the ground conditions. The exploratory holes are associated with Caltrans structures that cross the proposed alignment (from northwest to southeast). The stratigraphy discussed below is based on exploratory holes up to 1,000 feet either side of the proposed alignment that includes three of the five holes. The other two holes show a similarly variable sequence and are included on the geological cross section for comparison. Following a review of the Caltrans Log of Test Borings for the intersection of Highway I-99 and East North Avenue and the proposed alignment, the general stratigraphy can be described as follows:

- GL to 12 feet bgs (EL: 287 to 275 feet ASL) — Alternating beds of medium dense to very dense poorly graded sand and silty sand (SPT N 10–60); including possible hard pan at shallow depth.
- 12–17 feet bgs (EL: 275 to 270 feet ASL) – Beds of medium dense to very dense silt (SPT N 11–60).
- 17–32 feet bgs (EL: 270 to 255 feet ASL) – Alternating beds of medium dense to dense poorly graded sand and silty sand (SPT N 20–33).
- 32–42 feet bgs (EL: 255 to 245 feet ASL) – Medium dense silt (SPT N 13–18). This silt layer is usually significantly stronger, (up to SPT N of 200); however, when associated with groundwater, as it is here, it has become noticeable weaker and may suggest the potential for hydrocompaction or liquefaction if located at a shallower depth.
- 42–57 feet bgs (EL: 245 to 230 feet ASL) – Alternating beds of dense to very dense poorly graded sand and silty sand (SPT N 27–170).
- Groundwater was recorded consistently in two boreholes at 35 feet bgs (EL: 252 feet ASL).

These deposits are considered to be of fluvial origin. Figure A9c presented of Appendix A shows the geological cross section for the exploratory holes discussed above.

3.9.2 Subsection FB-B Rural North

Two sets of historical exploratory holes fall within the Rural North section, these holes were drilled by Caltrans in 1965 and 2002 as part of the construction or upgrade of Highway 41 in the town of Easton and of Highway 99 in Fowler. The exploratory holes in Easton are located approximately 2.5 miles west of the proposed alignment and the exploratory holes in Fowler are located approximately 8 miles southeast of the proposed alignment. The stratigraphy discussed below is based on the exploratory holes drilled in Easton because the exploratory holes in Fowler

are too far away to be of use in these variable ground conditions, but they are included on the geological cross section for comparison

Following a review of the Caltrans Log of Test Borings for the Rural North subsection the general stratigraphy can be described as follows:

- GL to 15 feet bgs (EL: 275 to 260 feet ASL) – Alternating beds of medium dense poorly graded sand and silty sand (SPT N 10–12).
- 15 feet – 25 feet bgs (EL: 260 to 250 feet ASL) – Beds of medium dense to very dense silt (SPT N 24–52).
- 25 feet to 55 feet bgs (EL: 250 to 220 feet ASL) – Alternating beds of medium dense to dense poorly graded sand, silty sand and silt (SPT N 24–38).
- 15 feet – 25 feet bgs (EL: 260 to 250 feet ASL) – Alternating beds of medium dense to dense silt and poorly graded sand with clay (SPT N 14–41).
- Groundwater was recorded at 35 feet at Easton (falling to 50 feet bgs at Fowler).

These deposits are considered to be of fluvial origin. Figure A10 presented in Appendix A shows the geological cross section for the exploratory holes discussed above.

3.9.3 Subsection FB-C Kings River Crossing

Two sets of historical exploratory holes fall within the Kings River subsection, these holes were drilled by Caltrans in 1984 and 1993 as part of the construction or upgrade process for a local road across the Kings River. The 1984 exploratory holes are located approximately 500 feet east of the proposed alignment and the 1993 exploratory holes are located approximately 1500 feet east of the proposed alignment. The stratigraphy discuss below is based primarily on the exploratory holes drilled in 1984 as the exploratory holes drilled in 1993 are deemed too far away to be of use in these variable ground conditions and are included on the geological cross section for comparison.

Following a review of the Caltrans Log of Test Borings for the Kings River Crossing the general stratigraphy can be described as follows:

- GL to 55 feet bgs (EL: 270 to 215 feet ASL) – Alternating beds of loose to very dense poorly graded sand, silt, poorly graded sand with clay and silty sand (SPT N 6–130).
- 55 feet to 70 feet bgs (EL: 215 to 200 feet ASL) – Alternating beds of dense to very dense silt and silty sand (SPT N 42–99).
- Groundwater was recorded at 20 feet bgs (EL: 250 feet ASL).

These deposits are considered to be of fluvial origin. Figure A11 presented of Appendix A shows the geological cross section for the exploratory holes discussed above.

3.9.4 Subsection FB-D Hanford Station

Three sets of historical exploratory holes fall within the Hanford section, these holes were drilled by Caltrans in 1964 as part of the construction process for Highway 198. The groups of exploratory holes are associated with Caltrans structures that cross (from east to west) an unnamed river 3.4 miles east of the alignment, Highway 43 approximately 0.5 miles west of the proposed alignment and N 10th Avenue approximately 2.5 miles west of the proposed alignment. The stratigraphy discussed below is based primarily on the exploratory hole FBE0451h drilled for

the Highway 198/43 crossing as the other exploratory holes are deemed too far away to be of use in these variable ground conditions.

Following a review of the Caltrans Log of Test Borings for the Highway 198/43 crossing the general stratigraphy can be described as follows:

- GL to 27 feet bgs (EL: 265 to 238 feet ASL) – Alternating thin to medium beds of medium dense sand (SPT N 14–35) and stiff silt (SPT N 27).
- 27 feet to 57 feet bgs (EL: 238 to 208 feet ASL) – Alternating thin to medium beds of medium dense to dense (SPT N 14–75) silty sand and clayey sand.
- Groundwater was not recorded.

These deposits are considered to be of fluvial origin. Figure A12 presented of Appendix A shows the geological cross section for the exploratory holes discussed above.

Three sets of historical exploratory borehole logs are available from Caltrans within the vicinity of the West Hanford alternative alignment. The boreholes were drilled in association with highway undercrossing construction works at Hanford Armona Road and 14th Avenue located to the west of alignment, and 11th Avenue undercrossing located to the east of the alignment.

The boreholes drilled at Hanford Armona Road undercrossing were completed in 1963. The ground conditions were found to comprise slightly compact to compact sands becoming loose to dense at depth. At a depth of approximately 18 feet bgs, a horizon of very soft dark grey organic silt (approximately 5 feet in thickness) was encountered.

In the boreholes completed at the 14th Avenue undercrossing located to the east of the Hanford Armona Road location, a clayey silt horizon was also encountered around 20 feet below ground surface. The material is described as being a ‘stiff yellow brown clayey silt’ and is approximately 5 feet in thickness. The material in underlain by what is described as a ‘hard tan silty clay to clayey silt’.

Boreholes drilled in 1965 for the 11th Avenue undercrossing located to the east of the West Hanford alignment are dominated by compact sandy silt and silty sands becoming typically dense sand at depth. At approximately 18 feet below ground surface (225 feet) a ‘soft to stiff brown clayey silt’ was encountered. The horizon extended to a depth of approximately 218 feet (7 feet in thickness).

3.9.5 Subsection FB-E Rural Central

Historical exploratory holes logs are available at three locations within the Rural Central subsection:

- Caltrans log of test borings are associated with the construction of or subsequent upgrades to local roads located 6 miles north of Corcoran and 2,000 feet to the west of the proposed alignment.
- Town of Corcoran planning department test borings located in Corcoran itself and on the proposed alignment. These boreholes are only 10 feet deep and therefore are not considered deep enough to be part of this assessment.
- Town of Corcoran planning department test borings located in a sewage treatment works between the two alternative alignments and up to 2,000 feet away from the proposed alignments.

Three sets of historical exploratory holes fall within the area 6 miles north of Corcoran, these holes were drilled by Caltrans in 1952 (1 hole), 1982 (1 hole) and 1997 (3 holes) as part of the construction or upgrades of some local roads six miles north of Corcoran. Following a review of the Caltrans Log of Test Borings for the area 6 miles north of Corcoran, the general stratigraphy can be described as follows:

- GL to 90 feet bgs (EL: 210 to 120 feet ASL) – Alternating beds of loose to medium dense silt and clayey sand or soft to firm locally stiff lean clay and elastic silt (SPT N 4 – 30).
- Groundwater was not recorded.

These deposits are thought to be of lacustrine and fluvial origin. Figure A13a presented of Appendix A shows the geological cross section for the exploratory holes discussed above.

The six historical CPT holes were constructed in the sewage works 2,000 feet east of Corcoran and between the two alignment alternatives were excavated in 2005. Following a review of the CPT logs the general stratigraphy can be described as follows:

- GL to 7 feet bgs (EL: 212 to 205 feet ASL) – Beds of silt.
- GL to 7 feet bgs (EL: 212 to 205 feet ASL) – Alternating beds of poorly graded sand, silty sand and silt.
- Groundwater was recorded at 22 feet bgs (EL: 190 feet ASL).

These deposits are considered to be of lacustrine and fluvial origin. Figure A13b presented of Appendix A shows the geological cross section for the exploratory holes discussed above.

3.9.6 Subsection FB-F Tule River Crossing

One set of historical exploratory holes fall within the Tule River Crossing subsection. These holes were drilled by Caltrans in 1971 as part of the construction of a local road of the Tule River and are located less than 100 feet from the proposed alignment. Following a review of the Caltrans Log of Test Borings for the Tule River Crossing the general stratigraphy can be described as follows:

- GL to 15 feet bgs (EL: 200 to 185 feet ASL) – Alternating beds of very loose to loose silty sand and soft silty clay (SPT N 3 – 10).
- 15 feet to 50 feet bgs (EL: 185 to 150 feet ASL) – Alternating beds of soft to very stiff silt and loose to very dense silt and silty sand (SPT N 9 – 70).
- 50 feet to 75 feet bgs (EL: 150 to 125 feet ASL) – Alternating beds of medium dense to very dense poorly sorted sand, silty sand and sand (SPT N 21–100).
- Groundwater was not recorded.

These deposits are considered to be of lacustrine and fluvial origin. Figure A14 presented of Appendix A shows the geological cross section for the exploratory holes discussed above.

3.9.7 Subsection FB-G Rural South

Available borehole data are nearly non-existent along HST Subsection FB-G. At the northern reach of this segment in the vicinity of HST Subsection FB-F Tule River Crossing, three boreholes are available within 500 feet of the Tule River. These boreholes show loose silty sand or soft clayey silt to a depth of 10 feet (Caltrans 1971). Underlying this is a layer of stiff silt to a depth of

20 feet overlaying a thin layer of harder material. Underlying this is interbedded dense silt and silty sand which grades to very dense silt and sand between EL 155 feet and EL 135 feet. Groundwater readings were not recorded.

At the Deer Creek Crossing there is a series of borings, however the borings are nearly 7.5 miles to the east of the alignment where Highway 99 crosses Deer Creek; thus, their usefulness for the purposes of this study are dubious at best. The borings extend to between 70 and 80 feet deep. N-values (blow counts) above EL 240 feet (between 0 to 20 feet bgs) generally range from 4 to 14 corresponding to very loose to medium dense silty fine sands. Between 20 and 50 feet bgs N-values generally range between 15 to 32 corresponding to medium dense to dense fine to medium sands and silty fine sands. Between 50 to 80 feet bgs N-values range between 30 to 60 corresponding to dense to very dense sandy silts, silty fine to medium sands.

At County Line Road on the north side of Delano, there is a series of borings, however the borings are nearly 5.5 miles to the east of the alignment where Highway 99 crosses County Line Road; thus, once again, their usefulness for the purposes of this study are dubious at best. The borings extend to between 60 and 70 feet deep. N-values in the upper 20 feet generally range from 3 to 15 corresponding to very loose to medium dense silty fine sands, sandy silts and poorly graded sands. Between 20 and 50 feet bgs N-values generally range between 10 to 36 corresponding to medium dense to dense fine to medium sands and silty fine sands and well to poorly graded fine sands. Between 50 to 70 feet bgs N-values range between 11 to 30 corresponding to medium dense sandy silts and silts with fine sand.

At the south side of Delano on Highway 99 there is another series of borings at Airport/Woollomes Road. These boring show essentially the same stratigraphy as the County Line Road.

At Poso Creek on the HST alignment (SR 43) there are two borings between 30 and 40 feet deep, however, these borings do not show N-values. The upper 10 to 15 feet consists of coarse sand followed by various thicknesses of clayey silts, silty clays and silty fine sand. Blow counts taken with a “hand hammer” generally increase and order of magnitude below a depth of 15 feet indicating the stratigraphy becomes denser with depth.

These deposits are considered to be of lacustrine and fluvial origin. Figure A15 of Appendix A shows the stratigraphy along this segment where the quality of the boring log data allowed.

3.9.8 Subsection FB-H Wasco and Shafter

Available borehole data are non-existent along HST Subsection FB-H. The nearest bore logs are nearly 4 miles to the east of Wasco at the Calloway Canal crossing on the Paso Robles Highway heading toward Famoso. Another set of bore logs is available on the same route at the Friant-Kern canal crossing more than 5 miles from the HST alignment. Finally, there are three sets of borings in the Famoso area more than 6.75 miles east of the alignment.

At the Calloway Canal Crossing on the Paso Robles Highway there is a series of one boring and three CPT logs. The boring log extends to about 70 feet below grade while the CPT logs extend 50 to 60 feet bgs N-values (blow counts) above EL 345 feet (between 0 to 30 feet bgs) generally range from 3 to 12 corresponding to very loose to loose, fine to coarse sands and soft to stiff sandy silts. Between EL 345 and 330 N-values generally range between 22 to 28 corresponding to medium dense to dense fine to coarse sands and stiff fine sandy silts. Below EL 345 N-values range between 43 to 50 corresponding to dense to very dense silty, clayey, fine to medium sands.

At the Friant-Kern Canal Crossing on the Paso Robles Highway there is a series of three borings and two CPT logs. The boring logs extend to between 30 and 80 feet bgs while the CPT logs

extend 80 feet bgs N-values (blow counts) in the upper 15 feet above EL 380 feet range from 8 to 39 corresponding to very loose to dense sandy silts, silty sands and fine to medium sands. Between EL 380 and 350 N-values generally range between 22 to 53 corresponding to medium dense to very dense, very fine to medium sands and stiff, fine, sandy silts. Between EL 350 and 330 N-values range between 58 to >70 corresponding to dense to very dense silty, clayey, fine to medium sands with some cementation noted. Below EL 320 in the bottom 10 feet of the borehole N-values drop to between 20 and 24 in a compact clayey silt but then increase again at the very bottom of the hole to <70 in a very dense silty sand.

Boring logs and CPT data in Famoso area are simply too far away (6.75 miles) to be considered of any value and surface elevations are about 80 feet high than at the HST alignments. Moreover, the data are of very poor quality. In general, however, the boring and CPT show similar soil constituents and trends of increasing stiffness with depth.

There were no borings of sufficient quality or within reasonable proximity directly along the alignment to justify showing the stratigraphy graphically on a figure.

3.9.9 Subsection FB-J Bakersfield North

There is only one useable boring log within Subsection FB-J at the intersection of the HST alignment and Highway 58 in Greenacres. In general, the boring log shows loose to slightly compact, silty, fine to medium and fine to coarse sands to a depth of 15 feet with N-values ranging between 14 and 17. At about 15 to 30 feet bgs exist dense to very dense sands and compact sandy, silts with N-values ranging between 28 and 32. Below this horizon N-values increase to between 62 and greater than 70 in some instances to the bottom of the boring at a depth of 45 feet bgs.

Figure A16 of Appendix A show the stratigraphy along this segment where the quality and proximity of the boring log data allowed.

3.9.10 Subsection FB-K Kern River Crossing

The geologic unit anticipated to be encountered in this segment is the Holocene-age Kern River Alluvial Fan which is composed of deposits of highly interstratified and discontinuous beds of clay, silt, sand and gravel, derived from the Kern River. The sand and gravel deposits within the alluvial fan were deposited in channels and finer grained material within overbank deposits. These sand and gravel deposits are highly permeable, but are imbedded with less permeable areas comprised of fine-grained silt and clay deposits. The approximate contact with Cretaceous marine sedimentary rock is located at a depth of approximately 2,500-feet below the surface (Wagner et al. 1987). The approximate contact with metamorphic/granitic basement rock is located at a depth of more than 18,000 feet below the surface of the project Bartow 1991.

The only Caltrans boring log data specifically along the alignment within Segment K is at the eastern most reaches between Highway 99 and Oak St. There are, however, several Caltrans data sets north of the alignment along Highway 58 as discussed below. Additionally, there are several geotechnical design reports associated with the proposed Westside Parkway and Mohawk Interchange Improvement which are pertinent to the HST alignment in this section.

At the intersection of the HST alignment and Highway 99 are several boring logs. In general, the boring logs show loose to slightly compact silty, fine to medium micaceous sands and silts to a depth of 20 to 25 feet with N-values ranging between 5 and 22. Between about 20 to 40 feet bgs are both micaceous sands and silts that are compact or medium dense to dense with increasing amounts of gravelly sands and N-values ranging between 28 and 55. Below this horizon N-values range to above 45 and greater than 70 in some instances with an increasing percentage of gravel.

Extrapolating from borings along Highway 58 (about 1 mile north of the alignment between Sta 7003+00 and Sta 7058+00) at the Calloway Canal and Friant-Kern Canal crossings there are several data sets that depict very similar soil profiles. In general, the boring logs show loose to slightly compact, silty, fine to coarse micaceous sands to a depth of 20 to 25 feet with N-values ranging between 5 and 18. At about 40 to 50 feet bgs exist both micaceous sand and silt that are compact or medium dense to dense with N-values ranging between 22 and 43. Below this horizon N-values increase to above 45 and greater than 70 in some instances.

Dokken (2008) reports that at the Mohawk Interchange (i.e., the intersection of Mohawk and the Westside Parkway) the average soil conditions along the length of the site to an explored maximum depth of 81.5-feet, consist of predominantly continuous, very loose to very dense, poorly graded/well-graded sand to silty sand, including traces of occasional fine to coarse gravels. Interbeds of discontinuous, fine grained soil consisting of stiff to hard clay, clay with sand, silt, silt with sand/sandy silt, with trace amounts of fine to coarse gravel, exist within thicker coarser grained units. Thicknesses of the fine grained soils varied from approximately 1-foot to 15-feet thick across the site at various depth intervals. Discontinuous units of dense, poorly graded gravel with sand, very dense clayey gravel with sand, and very dense well-graded gravel with sand, ranging from 2-feet to 10-feet thick, exist at depths of approximately 36-feet to 55-feet bgs north of the Kern River. In general, similar trends of increasing N-values as those described above are observed in the Dokken (2008) boring logs.

Kleinfelder (2008b) reports that soils along Segment 2 of the Westside Parkway are generally normally consolidated to slightly over consolidated alluvium. In general, the near surface soils encountered at the test boring locations consist of relatively clean poorly graded sand and silty sand extending to the depths explored, 85 feet below existing grade. Intermittent layers of sandy silt were encountered in some of the borings. The consistency of the soil ranges from medium dense to very dense (relative density of about 75 to 90 percent). In general, similar trends of increasing N-values with depth as those described above are observed in the Kleinfelder boring logs.

Figures A17a and A17b of Appendix A show the stratigraphy along this segment where the quality and proximity of the boring log data allowed.

3.9.11 Subsection FB-L Bakersfield South

Extrapolating from borings along Highway 58 (about 1 mile south of the alignment) between Highway 99 and Union Ave there are several data sets that depict very similar soil profiles. In general, the boring logs show loose to slightly compact silty, fine to medium micaceous sands to a depth of 20 to 25 feet with N-values ranging between 5 and 18. At about 40 to 50 feet bgs are both micaceous sand and silt that are compact or medium dense to dense with N-values ranging between 22 and 43. Below this horizon N-values increase to above 45 and greater than 70 in some instances with an increasing percentage of gravel.

At the intersection of Oswell St and Highway 58 about one mile south of the alignment (Sta 7430+00) is a series of two boring logs and two CPT logs. The quality of the data is reasonable. The boring log indicates very soft to soft clayey silts and clays and loose to compact sands with N-values ranging between 2 and 11 in the upper 50 to 60 feet bgs (EL 390 to EL330). Between 60 and 80 feet bgs the stiffness of the ground tends to increase in similar soils. At a depth of 80 feet a very dense fine sand layer is encountered with N-values greater than 70.

At the intersection of Sterling Rd and Highway 58 about 0.85 miles south of the alignment (Sta 7458+80) is a series of one boring log and two CPT logs. However, the quality of the data is very poor. The boring log indicates stiff to very stiff silts and clayey silts in the upper 20 to 25 feet. Between 20 and 40 feet bgs the stiffness of the ground tends to increase in similar soils. At a

depth of 50 feet a soft clay layer is encountered then becoming very stiff at a depth of 60 feet grading into compact silts and dense to very dense silty sands to a depth of 80 feet bgs.

At the intersection of Fairfax Rd and Highway 58 about 0.68 miles south of the alignment (Sta 7487+00) is a series of one boring log and two CPT logs. However, the quality of the data is very poor. The boring log indicates silts and clayey silts in the upper 25 to 30 feet with increasingly stiff sands and sands silts below that depth.

At the intersection of Magunden Rd and Highway 58 – a railroad spur over crossing — about 0.50 miles south of the alignment (Sta. 7531+80) is a series of one boring log and two CPT logs. However, the quality of the data is very poor. The boring log data are generally illegible however the CPT logs indicate an increase in soil stiffness/sand content below a depth of about 30 feet.

At the intersection of Weedpatch Highway (SR 184) and Highway 58– a railroad spur over crossing — about 0.40 miles south of the alignment (Sta. 7554+00) is a series of two boring logs and three CPT logs. However, the quality of the data is very poor. The boring log data are generally illegible but the CPT logs indicate an increase in soil stiffness/sand content below a depth of about 10 to 15 feet. The boring logs indicate the presence of coarse sands, fine to coarse sands, silty sands and sandy silts.

At the intersection of Vineland and Highway 58 (Sta. 7612+00) – where the HST alignment meets Highway 58 — is a series of one boring log and two CPT logs. However, the quality of the data is very poor. The boring log data are generally illegible but the CPT logs indicate an increase in soil stiffness/sand content below a depth of about 10 feet and another marked increase at about 30 feet bgs. The boring logs indicate the presence of coarse sands, fine to coarse sands, silty sands and sandy silts.

At the intersection of Edison Rd and Malaga Rd and Highway 58 (Sta. 7612+00) on the HST alignment are a series of boring log and CPT logs. However, the quality of the data is very poor. The boring log data are generally illegible but the CPT logs indicate and increase in soil stiffness/sand content below a depth of about 30 feet and another marked increase at about 60 feet bgs. The boring logs indicate the presence of coarse sands, fine to coarse sands, silty sands and sandy silts.

There were no borings of sufficient quality or within reasonable proximity directly along the alignment to justify showing the stratigraphy graphically on a figure.

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Section 4.0

Seismic Hazards

4.0 Seismic Hazards

4.1 Historical Seismicity

Seismicity refers to the frequency, distribution, and intensity of earthquakes in a specific geographic area. Historical records of seismic events are useful to confirm the geographic distribution and intensity of past earthquakes. These historical accounts are valuable in evaluating the frequency of earthquakes in particular regions. The Modified Mercalli Intensity (MMI) scale of 1930 describes earthquake intensity qualitatively, by interviewing witnesses and observing structural damage. The MMI scale describes progressive levels of ground shaking for intensity ranges varying between I to XII. Historically, areas that have experienced MMIs of less than VII have not suffered extensive damage. Qualitative descriptions of MMIs and their associated PGAs between VII and IX are as follows (Richter 1958):

- MMI VII (Moderate) — Difficult to stand. Noticed by car drivers. Hanging objects quiver. Furniture broken. Damage to masonry D including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices, unbraced parapets, and architectural ornaments. Some cracks in masonry C. Waves on ponds, water turned turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete culverts damaged. (PGA: 18–34%g)
- MMI VIII (Moderate to Heavy) — Steering of motorcars affected. Damage to masonry C: partial collapse. Some damage to masonry B, none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down, loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and steep slopes. (PGA: 34–65%g)
- MMI IX (Heavy) — General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. General damage to foundations. Frame structures shifted off foundations if not bolted down. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks on ground. Sand boils, earthquake fountains, and sand craters. (PGA: 65–124%g)

The descriptions of masonry types used in the MMI levels above are no longer in use. The masonry types in use at the time the MMI levels were developed are shown on Table 4.1-1.

Table 4.1-1
MMI Masonry Type Descriptions (Richter 1958)

Type	Description
Masonry A	Good workmanship, mortar, and design; reinforced, especially laterally, and bound together by using steel, concrete, etc.; designed to resist lateral forces
Masonry B	Good workmanship and mortar; reinforced, but not designed in detail to resist lateral forces
Masonry C	Ordinary workmanship and mortar; no extreme weaknesses like failing to tie in at corners, but neither reinforced nor designed against horizontal forces
Masonry D	Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally

With the application of seismometers to measure seismic waves in 1935, quantitative measurements of earthquake Mw and PGAs have since been available. Table 4.1-2 shows correlations between PGAs and the MMI scale.

Table 4.1-2
MMI versus PGA Empirical Correlations (USGS Website)

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

The USGS, CDMG, and CGS have widely published maps and databases of historical earthquakes, including location, magnitude, associated fault, and rupture length and area. These maps and databases have been reviewed to determine the frequency, distribution, and intensity of historical earthquakes in relation to the FB Section.

The locations of seismometers near the proposed alignment are concentrated in the southern reaches of the alignment as shown on Figure A4 of Appendix A. However, there are several stations near Visalia and Fresno that record ground motions in the northern reaches. The disparity in the number of stations between the north and south sections of the alignment shown on Figure A4 of Appendix A is likely due to the concentration of seismic activity in the south and the fact that the north is in a zone with no historical record of seismic damage. By superimposing the MMI intensities from shake maps (isoseismal maps) from the larger historical earthquakes, seismologists at the CDMG and USGS have constructed zones of historical damage in the SJV (and throughout California) (Peterson 1996). Figure 4.1-1 shows that most of the northern reaches of the alignment and only a small section of the Subsection FB-G study area have not historically suffered damage. However, the isoseismal map of the 1952 Kern County earthquake (Figure 4.1-4) suggests that subsection FB-G was subject to MMI VII intensity shaking.

CGS Map Sheet 49 indicates several large magnitude earthquakes that have been recorded near the FB Section. The dates, Mw, and epicenter locations of selected historical earthquakes are shown on **Table 4.1-3**.

Figure 4.1-1
Historical Zone of No Seismic Damage (after Peterson et al. 1996)

04/02/2014 - RFP No.: HSR13-57

Table 4.1-3
Selected Historical Earthquakes near Fresno to Bakersfield HST Alignment

Date	Moment Magnitude (Mw)	Epicenter		Name or Location
		Latitude	Longitude	
1857, Jan. 9	7.9	35.43	-120.19	Fort Tejon
1872, Mar. 26	7.4	36.70	-118.10	Owens Valley
1922, Mar. 10	6.3	36.10	-120.60	Parkfield
1940, May 19	7.0	32.73	-115.50	Imperial Valley
1946, Mar 15	6.0	35.73	-118.1	Walker Pass
1952, July 21	7.3	35.00	-119.02	Kern County
1971, Feb 9	6.6	34.41	-118.40	San Fernando
1979, Oct. 15	6.5	32.61	-115.32	Imperial Valley
1980, May 25	6.2	37.60	-118.85	Mammoth Lakes
1983, May 2	6.4	36.23	-120.31	Coalinga
1985, Aug. 4	6.2	36.12	-120.15	Kettleman Hills
1992, June 28	7.3	34.20	-116.44	Landers
1994, Jan 17	6.7	34.21	-118.54	Northridge
1999, Oct. 16	7.1	34.60	-116.27	Hector Mine
Source: CDMG Map Sheet 49				

This section is a discussion of those earthquakes most significant to the alignment within the study area and includes isoseismal maps showing the spatial extent of areas that have experienced damaging MMIs ranging between VII and IX for the most significant of these.

Descriptions of these historical quakes are primarily derived from online resources including websites of the USGS and the SCEC. Figure 4.1-1 shows the area along the alignment that has historically never been exposed to damaging ground motions. This zone falls outside the isoseismal maps of the most significant earthquake presented below.

4.1.1 1857 Fort Tejon: The Largest Earthquake in California

The M_w 7.9 Fort Tejon earthquake occurred along the San Andreas Fault, rupturing near Cholame, about 34 miles northwest of the Kings County border near Avenal. Hardon (2004) describes the earthquake as producing horizontal displacements of up to 30 feet in the Carrizo Plain and 10 to 13 feet in the Mojave Desert. The fault rupture for this earthquake extends a distance of around 185 miles from near Parkfield (in the Cholame Valley) to almost Wrightwood.

The earthquake caused one fatality. A comparison of this earthquake to the San Francisco earthquake, which occurred on the San Andreas Fault on April 18, 1906, shows that the fault rupture in 1906 was longer but the maximum and average displacements in 1857 were larger.

The Southern California Earthquake Data Centre (SCEDC) website (SCEDC a) describes the strong shaking associated with the Fort Tejon earthquake to have lasted from 1 to 3 minutes. As a result of the shaking, the current of the Kern River was turned upstream and water ran 4 feet deep over its banks. The waters of Tulare Lake were also thrown upon its shores, stranding fish miles from the original lakebed. California in 1857 was sparsely populated, especially in the regions of strongest shaking, which helped to keep the loss of life and damage to a minimum.

The earthquake was named after Fort Tejon, a US Army post in South Central Kern County about 4.3 miles from the San Andreas Fault, since it was the area of strongest reported shaking. However, the SCEDC website (SCEDC a) reports that there is evidence that foreshocks may have occurred in the Parkfield area and that the actual epicenter is thought to have been just southeast of Parkfield, just outside of Kern County's northwestern-most boundary. Figure 4.1-2 shows an isoseismal map of the geographical extent of the MMI VII to MMI IX intensities produced by this event.

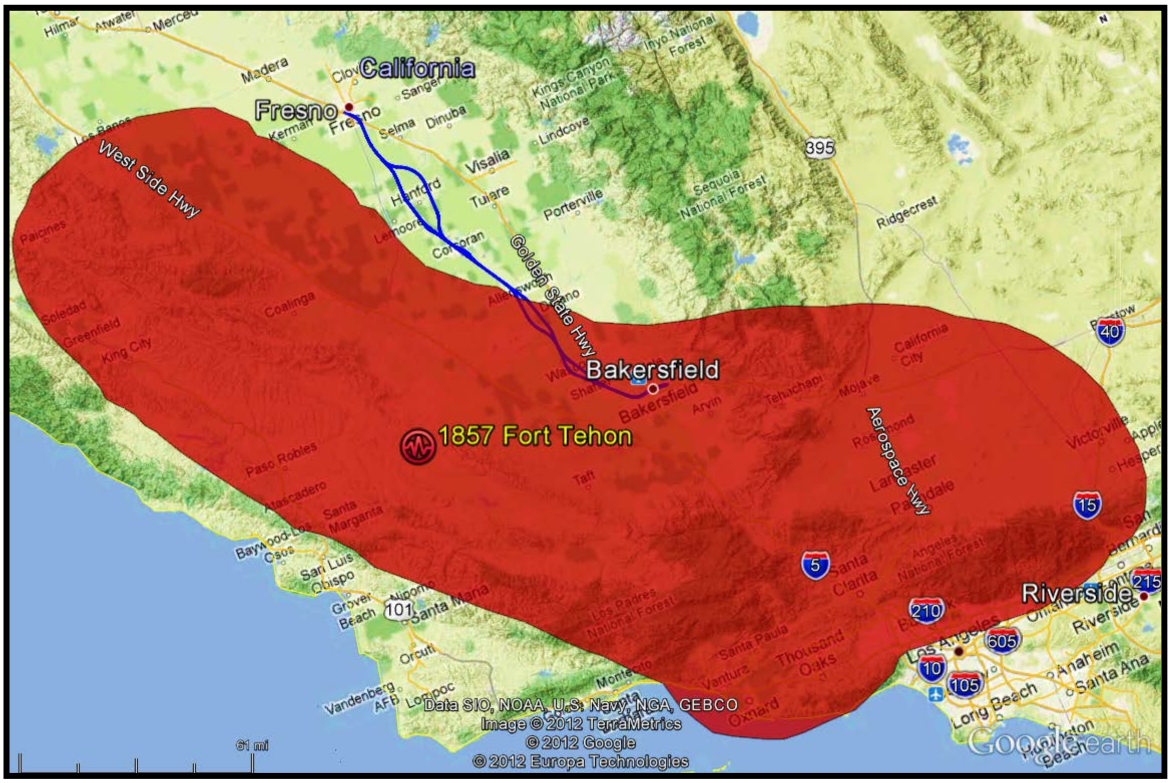

Figure 4.1-2
Isoseismal Map of 1857 Fort Tejon MMI VII–IX Shake Zone (after Stover et al. 1993)

4.1.2 1872 Owens Valley

The USGS historical quakes online database (USGS c) provides details of the major M_w 7.4 Owens Valley earthquake, which struck California on March 26, 1872. Figure 4.1-3 shows an isoseismal map of the geographical extent of the MMI VII to MMI IX intensities produced by this event.

Nearly all houses at Lone Pine (mostly constructed of adobe or stone) were destroyed and 27 people killed, with a few fatalities also reported in other parts of Owens Valley. One report stated that the main buildings were thrown down in almost every town in Inyo County. About 60 miles south of Lone Pine, at Indian Wells, adobe houses sustained cracks. Property loss was estimated at $250,000 in 1872 dollars ($5.5 million in 2010 dollars) (USGS c).

The faulting occurred on the Owens Valley fault along a line a few miles east of the Sierra Nevada escarpment. Near Lone Pine, the faulting comprised both dip-slip and right lateral components of movement. The largest amount of surface deformation was observed between the towns of Lone Pine and Independence, but fault scarps formed along a length of at least 100 miles — from Haiwee Reservoir, south of Olancho, to Big Pine (USGS c).

The USGS earthquakes database report goes on to describe that cracks were formed in the ground as far north as Bishop. The largest horizontal displacement of 33 feet was measured on the fault scarps west of Lone Pine, with vertical offsets averaging about 3 feet. A comparison of this earthquake to the earthquakes of 1857 and 1906 on the San Andreas Fault shows the fault area and maximum fault displacements to be comparable. However, the shocks on the San Andreas fault ruptured significantly larger distances (185 miles in 1857 and 270 miles in 1906, respectively) (USGS c).

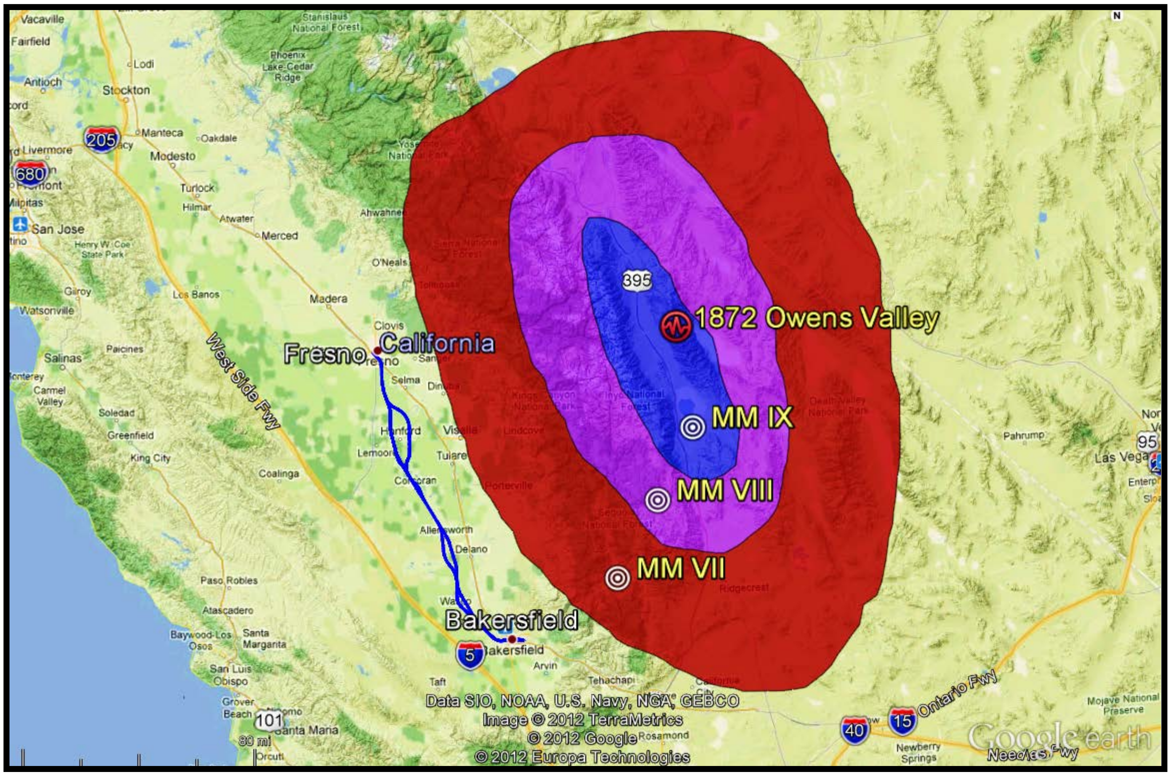

Figure 4.1-3
Isoseismal Map of 1872 Owens Valley MMI VII-IX Shake Zones (after Stover et al. 1993)

4.1.3 1946 Walker Pass

The main shock of the M_w 6.3 Walker Pass earthquake caused moderate damage at Onyx, located about 12 miles southwest of the epicenter. Considerable damage to structures (wood, brick, masonry, concrete, etc.) was reported. Cracks were noted in the ground and in concrete along the Los Angeles Aqueduct. In the region of Walker Pass and the South Fork of the Kern River, adobe houses were damaged, brick chimneys cracked, and plaster fell (geology.com).

4.1.4 1952 Kern County (Arvin-Tehachapi)

The M_w 7.3 Kern County earthquake occurred along the Bear Mountain Segment of the White Wolf Fault Zone, a southeast dipping, left-lateral reverse fault approximately 45 miles long.

The White Wolf Fault is traceable for only approximately 34 miles and had previously not been considered capable of producing such a large magnitude earthquake (SCEDC b). USGS describes this earthquake (also known as the Arvin-Tehachapi Earthquake) as the largest in the conterminous United States since the San Francisco shock of 1906 (USGS d). It claimed 12 lives and caused property damage estimated at $60 million.

Significant damage occurred to major infrastructure, including cracking of a reinforced concrete tunnel with 18-inch-thick walls on the Southern Pacific Railroad southeast of Bealville. The earthquake shortened the distance of the tunnel portals by 8.2 feet and bent the rails into S-shaped curves. As a result of this damage, an MMI of IX was assigned to this small area. At Owens Lake (about 100 miles from the epicenter), salt beds shifted and brine lines were bent into S-shapes (USGS d).

Surface rupture was observed along the lower slopes of Bear Mountain, in the White Wolf fault zone. Within the valley, poorly consolidated alluvium was observed to have been erratically cracked and recontorted. Bear Mountain is reported to have moved upward and to the north by several feet. Southwest of Arvin, on the SJV floor, ground cracks transverse and spit the concrete foundation of one house, causing partial collapse (USGS d).

USGS describes further examples of significant ground movements, including ground slumping, offset of cotton rows (more than 12 inches), and the crumpling of a highway for more than 1,000 feet. East of Caliente, a large surface crack, measuring 60 inches at its widest point and 24 inches deep occurred (USGS d). In the fill areas in the mountainous regions of Highway 58, the ground was displaced vertically about 24 inches and horizontally about 18 inches.

As shown on Figure 4.1-4, the maximum intensities associated with the earthquake in nearby cities did not exceed VIII. USGS describes the damage that occurred in towns within close proximity of the proposed route alignment:

> In Tehachapi, Bakersfield, and Arvin, old and poorly built masonry and adobe buildings were cracked, and some collapsed. Property damage was heavy in Tehachapi, where both brick and adobe buildings were severely damaged, and 9 people were killed. The generally moderate damage in Bakersfield was confined mainly to isolated parapet failure. Cracks formed in many brick buildings, and older school buildings were moderately damaged. In contrast, however, the Kern General Hospital was heavily damaged. Multistory steel and concrete structures sustained minor damage, which was commonly confined to the first story. Similar kinds of damage also occurred at Arvin, which lies southeast of Bakersfield and west of Tehachapi. (USGS b)

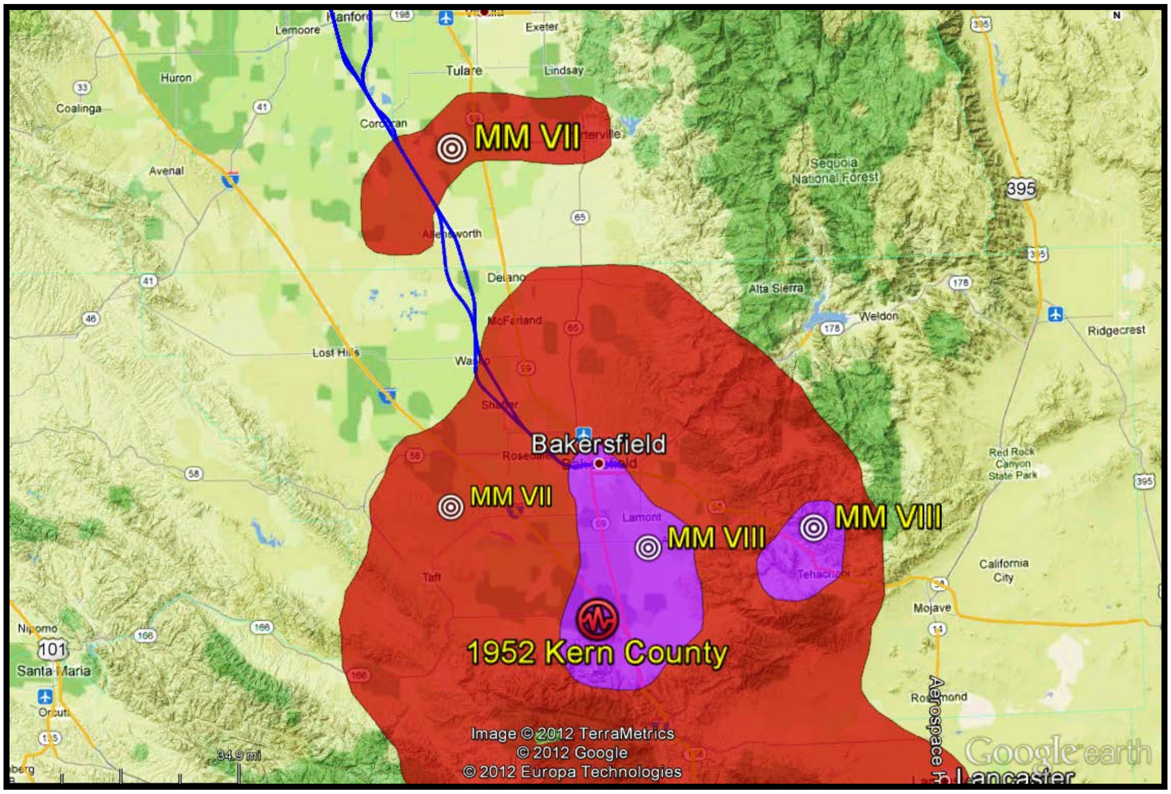

Figure 4.1-4

Isoseismal Map of 1952 Kern County MMI VII-VIII Shake Zones (after Stover et al. 1993)

4.1.5 1971 San Fernando

The 1971 San Fernando M_w 6.6 earthquake occurred in the San Gabriel Mountains, near San Fernando. The area was sparsely populated; however, the earthquake lasted about 60 seconds and 65 lives were lost and more than 2,000 people were injured (USGS e).

USGS describes the earthquake exposing a zone of discontinuous surface faulting named the San Fernando fault zone. The fault zone partly follows the boundary between the San Gabriel Mountains and the San Fernando-Tujunga Valleys, and partly transects the northern salient of the San Fernando Valley. This tectonic zone of rupture was associated with some of the heaviest property damage sustained in the region. The maximum vertical offset measured on a single scarp over the length of the surface faulting was at 3.25 feet, with a maximum shortening (thrust component) of around 3 feet (USGS e).

4.1.6 1983 Coalinga

The M_w 6.4 Coalinga earthquake (see Figure 4.1-5) was the result of a 20-inch uplift of Anticline Ridge northeast of Coalinga. Ground rupture was not observed during the main shock. Instead, the top few kilometers of the crust elastically folded. However, the subsequent aftershock caused surface rupture about 7.5 miles northwest of Coalinga. About 2.1 miles of right-reverse ground rupture occurred on the Nunez fault, accompanied by about 3.25 feet of oblique slip (USGS f).

Bridge surveys after the event revealed relatively minor structural damage consisting of hairline cracks and spalling at the top of the support columns, fracturing and displacement of wing walls and parapets, and settlement of fill (USGS f).

The earthquake caused an estimated $10 million ($22 million in 2010 dollars) in property damage and injured 94 people. Damage was most severe in Coalinga, where the eight-block downtown commercial district was almost completely destroyed. Coalinga buildings with unreinforced brick walls sustained the heaviest damage, while newer buildings sustained only superficial damage. The most significant damage outside the Coalinga area occurred at Avenal, 20 miles southeast of the epicenter (USGS f).

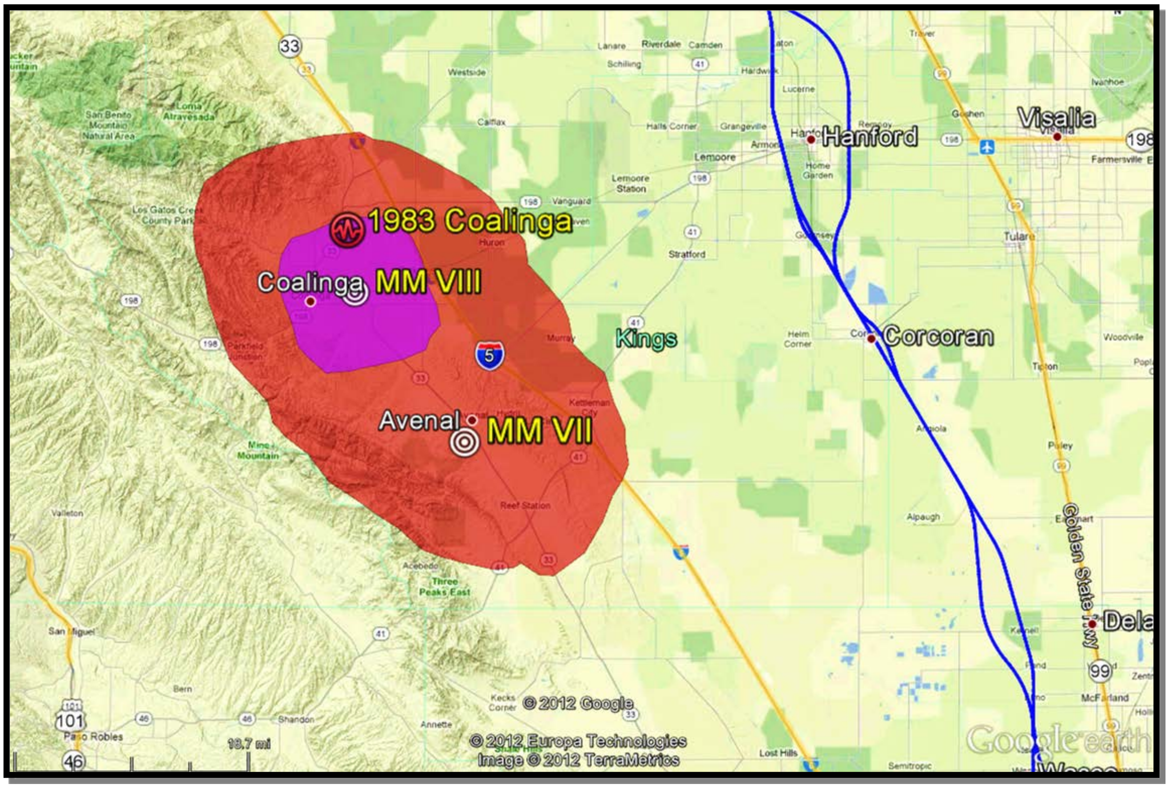

Figure 4.1-5

Isoseismal Map of 1983 Coalinga MMI VII-VIII Shake Zones (after Stover et al. 1993)

4.1.7 1985 Kettleman Hills

As detailed in the 2007 Kings County Multi Hazard Mitigation Plan (MHMP), the M_w 6.1 Kettleman Hills earthquake was located four miles from the Kings County border just north of Avenal. It was the third in a sequence of moderate earthquakes, preceded by the 1982 New Idria earthquake (M_w 5.4) and the 1983 Coalinga (M_w 6.4). The New Idria, Coalinga, and Kettleman Hills earthquakes struck on a series of west-dipping, echelon blind thrust faults (USGS Open-File Report 2006-1149) associated with the Great Valley Fault System. The Kettleman Hills earthquake did not produce any ground surface rupture, and low levels of ground shaking were reported in Kings County (Kings County MHMP 2007).

4.1.8 1999 Hector Mine

The M_w 7.1 Hector Mine earthquake is the third largest earthquake to occur in Southern California in the 20th century. It occurred in the remote and undeveloped Mojave Desert region (Lund 1999).

The epicenter was approximately 120 miles north of Los Angeles, located on the Lavic (dry) Fault. The rupture was reported to be a 25-mile-long right-lateral surface rupture with a

maximum offset of 12.5 feet and a vertical offset of 5 feet. The earthquake is named after the open pit mine (Montmorillinite clay) located on a northerly extension of the Lavic Lake Fault (Lund 1999).

No lifelines were reported to be in the vicinity of the fault rupture. The earthquake was felt as far away as Las Vegas, Nevada; Phoenix, Arizona; Eugene, Oregon; and San Diego, California (Lund 1999).

The earthquake derailed a train on the BNSF Railroad around 15 miles west of Ludlow, near the northerly extension of the Lavic Fault. All 24 cars (12 passenger and 12 express) were derailed, with the three locomotive units remaining on the track. Only four people received minor injuries (Lund 1999).

Approximately 20 miles north of the epicenter, a 15-mile section of track and minor bridges experienced damage, including buckled track, disturbance to track geometry, and displacement of ballast. No rail joints are reported to have been pulled apart. In total, six bridges required minor repairs, primarily to wing walls. In the segment between the first and last damaged bridges, 27 bridges were undamaged (Lund 1999).

4.2 Potential Seismic Sources

Strain energy accumulates as shear stresses and increases along plate boundaries as a result of tectonic movement. When these building shear stresses cause the rock near these boundaries to fail, the stored strain energy is released (Kramer 1996). Earthquakes are caused by the relief of this strain energy from faults. Faults, defined as cracks in the earth's crust resulting from the displacement of one side with respect to the other, may vary from several feet to hundreds of miles and extend from the ground surface to tens of miles deep.

Characterizing faults is critical to estimating the Maximum Considered Earthquake (MCE) or Mw that a particular fault may produce. Factors such as rupture length, rupture area, and fault displacement can be correlated with the earthquake magnitude to describe future earthquake potential (Kramer 1996). In accordance with TM 2.9.3, the project team reviewed the USGS and CGS fault database and the project Geologic and Seismic Hazards GIS database to identify potential seismic sources near the FB Section. All known active or potential active faults near the FB Section are shown on Figure A3 of Appendix A. Table 4.2-1 presents elected major faults, Mw, and recurrence intervals, and Table 3.5-1 shows fault types, slip rates, and distances to the alignment.

Table 4.2-1
Seismic Characteristics of Capable Faults

Fault Name	Moment Magnitude (M_w)	Recurrence Interval (yr)
Great Valley Fault (Seg 13)	6.5	-
Ortigalita	7.1	2,000–5,000
San Joaquin	6.9	-
O'Neill	6.7	-
Foothills	6.5	12,500
Round Valley/Hilton Creek	7.0/6.7	-
Clovis Fault	-	-
Owens Valley	7.6	2,000–3,000
Kern Canyon	7.0	-
Kern Front	6.5	-
Kern Gorge	7.0	-
Southern Sierra Nevada (Independence Section)	7.1	-
Breckenridge/Kern Canyon	6–8	12,500
Southern Sierra Nevada	7.75	-
Garlock	7.5–8.0	700–1,200
Oil Field Fault Zone	6.25	-
Great Valley 14	6.4	-
Wheeler Ridge/Pleito Trust	7.0	-
Owens Valley	7.6	3,000–5,000
White Wolf	7.3	1,000–5,000
San Andres: Carrizo–Cholame Segment	7.4	160–450
San Andres: Parkfield Segment	6.5	20

Note: indicates no data available
Source: USGS 2002 CA Fault Parameters,
Metropolitan Bakersfield General Plan Chapter VIII
Caltrans 2007 Online Fault Database
Caltrans 2007 Deterministic PGA Map

4.3 Ground Rupture

Earthquakes are generally accompanied by movement along faults that can vary from inches to tens of feet. Most movements occur deep below the subsurface and do not breach the surface (Krinitzsky 1993). However, severe earthquakes at transform boundaries may be accompanied by ground rupture. Ground rupture or surface fault rupture may cause zones of cracks, rumples, and horizontal displacements that are damaging to structures located within the surface rupture zone (Harder 2004).

In accordance with TM 2.9.3, the RC completed an evaluation of seismogenic sources, which included review of fault databases available through the USGS, CGS, Caltrans, UBC, IBC, SCEC, and WGCEP. Review of these resources, as well as the HST Geologic and Seismic Hazards GIS Database, indicates that no active faults or near source zones cross the FB Section. However, it is possible that primary fault rupture along branch faults can be distributed across zones hundreds of feet wide or manifested as broad warps (CGS Note 49 2002). The evaluation of a given site with regard to the potential hazard of surface fault rupture is based extensively on the concepts of recency and recurrence of faulting along existing faults (CGS Note 49 2002). In general, more recent fault activity increases the probability for future faulting, as long-inactive faults are less likely to be reactivated (CGS Note 49 2002). To evaluate the recency of fault activity, a site-specific surface fault rupture study is required. The required study includes a field investigation, usually by excavation and logging of a trench, to map potentially active fault traces, which has not been carried out as part of this project

To minimize the hazard of surface fault rupture, the AP Earthquake Fault Zoning Act was signed into California state law in 1972. The AP Act prohibits the location of most structures intended for human occupancy within 50 feet of a known active fault. Geologic reports are required to address the potential for surface faulting for all projects intended for human occupancy (CDMG SP 42 1999).

The CGS defines an *active fault* as one that has had surface displacement within Holocene time (last 11,000 years) and a *sufficiently active fault* as one that has evidence of Holocene surface displacement along one or more of its segments or branches (CDMG SP 42 1999). The CGS considers a fault to be well defined if its trace is clearly detectable as a physical feature at or just below the ground surface (CDMG SP 42 1999). As a result, only faults or portion of faults with relatively high potential for ground rupture are zoned, while other faults that may partially meet the criteria are not zoned. The potential for fault rupture, therefore, is not limited solely to faults or portions of faults delineated as EFZs.

There are no AP Act EFZs in any county along the study area apart from Kern County. Within Kern County, the AP EFZs include the following:

- San Andreas Fault Zone.
- White Wolf Fault Zone.
- Garlock Fault Zone.
- Pond Fault.
- 1952 unnamed fault zones near the Oil Field Faults.
- Wheeler Ridge Fault Zone.
- Buena Vista Fault Zone.

Table 4.3-1 shows surface rupture characteristics associated with historical earthquakes near the FB Section.

None of the AP EFZs in Kern County actually intersect any of the proposed alignments within the study area. The AP EFZ in closest proximity to the alignment is associated with the 1952 unnamed faults east of the town of Edison with fault traces that encroach within a quarter mile north of the alignment (see Figure 3.5-7). The next closest AP EFZ to the alignment is the Pond Fault discussed previously (see Figure 3.5-5). This zone is located about 1.5 miles east of the alignment about a mile south of the town of Pond.

Table 4.3-1
Historical Surface Rupture of Faults

Year	Fault Name (Segment)	Moment Magnitude (M_w)	Surface Rupture Maximum Displacement (cm)	Total Rupture Length (km)
1983	Nuñez	5.2–5.9	60 Vert	3.3
1971	San Fernando	6.6	100 Vert: 100 Left Lateral	15.3
1966	San Andreas (Parkfield)	6.0	5 Vert: 17.8 Right Lateral	37
1952	White Wolf	7.4	122 Vert: 76 Left Lateral	57
1934	San Andreas (Parkfield)	6.0	3 V: 15 Right Lateral	32
1922	San Andreas (Cholame)	6.3	-	0.4
1906	San Francisco	7.8	90 Vert: 600 Right Lateral	432
1872	Owens Valley	7.4	3200 Vert: 1000 Horz	116
1857	San Andreas (Fort Tejon)	7.9	950 Right Lateral	322
Source: CGS (2010) Other fault data can be found on Table 3.5-1 **and** Table 4.2-1				

In contradiction to the CGS AP zone maps, Figure VIII-2 of the MBGP shows the AP EFZ that encompasses the 1952 unnamed faults also extending across the alignment and Highway 58 (see MBGP EFZ on Figure 3.5-7). This zone appears to tie in with the CDWR fault trace of the Edison Fault referenced in Section 3.5. The MBGP EFZ likely developed due to assessments by Bartow (1984) and Jennings (1994) that the western trace of the Edison Fault has demonstrated historical activity. The actual crossing of the Edison Fault at the alignment will be evaluated as part of the Bakersfield to Palmdale study since it is slightly outside of this study area.

In accordance with TM 2.9.3 § 6.1.1.2, a field reconnaissance survey of the study area was not carried out.

A field reconnaissance survey of the study area was conducted in May 2010 to confirm that no evidence of fault rupture is visible in surface features on the proposed southern part of the Fresno to Bakersfield part of the alignment. No evidence of surface rupture was observed within the study area during the reconnaissance.

4.4 Ground Shaking

Ground shaking refers to propagation of seismic waves to the ground surface as a result of an earthquake. Ground shaking from a severe seismic event may be felt hundreds of miles from the epicenter and generally causes the greatest damage during an earthquake (Harder 2004). The intensity of ground shaking is a function of the earthquake's magnitude, distance from the epicenter, depth below the surface, and subsurface ground conditions. Areas underlain with unconsolidated, saturated sediments are more prone to significant ground shaking than areas underlain by bedrock. Seismic ground shaking hazards are commonly characterized through the horizontal PGA or the MMI scale associated with a scenario or characteristic earthquake event. PGA is expressed in terms of the acceleration (g) due to the earth's gravity (g = 32.2 ft/s^2 [9.81 m/s^2]).

4.4.1 Peak Ground Acceleration

In accordance with TM 2.10.5, the project team reviewed USGS 2002 National Seismic Hazard Maps to determine potential ground shaking amplitudes (in terms of PGA) for a characteristic seismic event near the FB Section. Figure A18a of Appendix A presents contours of PGA associated with an event with 2% probability of exceedance (PE) in 50 years (recurrence interval of 2,475 years in accordance with TM 2.10.5), based on the USGS 2002 maps. Figure A18a of Appendix A was developed for the firm rock, Site Class B (V_S^{30}=2500 ft/s), and, thus, does not account for amplification effects through overburdened soils. Site classes are defined in Table 4.4-1.

PGA contours shown on Figure A18a of Appendix A indicate that the HST alignment between Fresno and Tule River Crossing is likely to experience relatively moderate levels of ground shaking ranging from 0.21g to 0.29g, as shown in Table 4.4-2**.** Within Subsection FB-G Rural South, the alignment is likely to experience light to moderate levels of ground shaking of between 0.29g to 0.37g during a characteristic earthquake event, with ground shaking increasing in a southerly direction. In Section FB-H Wasco and Shafter, ground shaking of between 0.37g to 0.46g is likely. Segments FB-J Bakersfield North and FB-K Kern River Crossing are also likely to experience moderate levels of ground shaking of between 0.46g to 0.48g. Based on the contours, Subsection FB-L Bakersfield South is likely to experience moderate to heavy ground shaking of between 0.48g to 0.54g. Localized areas underlain by loose or unconsolidated, saturated soils may experience even greater ground shaking intensity. PGA values at specific points on the alignment are provided in Table 4.4-2.

Although single-parameter descriptions of ground motion (such as PGA) are useful in estimating potential ground shaking intensity, they are not sufficient for the earthquake-resistant design of structures (Algermissen 2007). For engineering purposes, it is necessary to characterize the amplitude, frequency content, and duration of the earthquake, and site amplification effects to fully describe the site-specific ground motion (Kramer 2006). This typically includes conducting site-specific testing to determine local shear wave velocities through seismic CPTs, other down-hole geophysical testing techniques, or correlations to other in situ testing techniques such as conventional CPT, CPT_u, and SPT testing. In addition to PGA, other commonly used ground motion design parameters include peak horizontal velocity, predominant period, duration, and response spectra ordinates. A complete suite of seismic design ground motions parameters will be provided at the 30% design stage.

4.4.2 Site-Specific Response Spectra

The USGS 2002 National Seismic Hazard Maps provide plots of both the PGA and MCE spectral ordinates at 0.2 seconds (S_s) and 1.0 second (S_1) with 2% PE in 50 years (Figures A18b and A18c). These acceleration levels were computed for uniform "firm rock," Site Class B (V_s^{30} = 2500 ft/s), and, therefore, the potential spatial variability of ground motion associated with different site conditions is not considered (Kalkan 2010). In depicting the variability of earthquake hazard across a region, assuming a uniform "firm rock" condition across the area results in a pattern of ground motion that falls off smoothly from the major faults but misses the areas of high potential ground shaking due to amplification of seismic waves by the near-surface soils. This is commonly referred to as "site amplification."

Recognition of the importance of site amplification prompted the SCEC Phase III efforts to map site conditions at regional and state-wide scales. The SCEC "Phase III" Report (published in December 2000, in BSSA) has quantified how local geologic conditions, known as "site effects," contribute to the shaking experienced in an earthquake. The study identified that the most important geologic factors at a given site are as follows:

- The softness of the rock or soil near the surface (shaking is amplified in softer materials).

- The thickness of the sediments above hard bedrock (shaking is amplified where sediments are thicker).

One simple way of accounting for the first component of these site conditions in calculating seismic hazards is to use the shear-wave velocity in the shallow subsurface to classify materials. Conventionally, the average shear-wave velocity in the upper 100 feet/30 meters (V_S^{30}) is used to develop site classes/categories that can be used for modifying a calculated ground motion to account for site conditions. Site class descriptions grade from A to F as defined in the IBC (Table 4.4-1).

Table 4.4-1
Site Class Description (ICC 2006)

Site Class[1]	Soil Profile Name	Average Properties in Upper 100 ft (~30 m) Shear Wave Velocity, V_{s30}	
		ft/sec	m/sec
A	Hard rock	$V_{s30} > 5{,}000$	$V_{s30} > 1{,}524$
B	Rock	$2{,}500 < V_{s30} \leq 5{,}000$	$762 < V_{s30} \leq 1{,}524$
C	Very dense soil and soft rock	$1{,}200 < V_{s30} \leq 2{,}500$	$366 < V_{s30} \leq 762$
D	Stiff soil profile	$600 < V_{s30} \leq 1{,}200$	$183 < V_{s30} \leq 366$
E	Soft soil profile	$V_{s30} < 600$	$V_{s30} < 183$

[1] As defined in 2006 IBC Section 1613.5.5 (ICC 2006)

USGS provides preliminary maps for V_S^{30}, which are based on the research by Wald and Allen (2007) and efforts by Kalkan (2010). The initial methodology for deriving maps of seismic site conditions is based on using the topographic slope as an indicator for seismic site conditions and amplification. Slope of topography, or *gradient*, is judged to be diagnostic of V_S^{30} since more competent (high-velocity) materials are more likely to maintain a steep slope, whereas deep basin sediments are deposited primarily in environments with very low gradients. Furthermore, sediment fineness is an indicator for lower V_S^{30} (Park and Elrick 1998) and also relates to slope. For example, steep, coarse, mountain-front alluvial fan material typically grades to finer deposits with distance from the mountain front and is deposited at decreasing slopes by less energetic fluvial and pluvial processes. More recently, approximations of the geospatial distribution of V_S^{30} are correlated directly to geologic unit types (Kalkan 2010). Figure A30 Appendix Aof Appendix A presents the latest geospatial distribution of V_S^{30} as correlated directly to geologic unit types. Figure A30 of Appendix A shows the distribution of the average shear wave velocity along the FB Section which is comparable with Site Class D (600 ft/s< V_S^{30} < 1200 ft/s) as recommended in TM 2.10.5 in this study. The USGS preliminary V_S^{30} maps are based on a simplified approach and should not be considered definitive for any specific location or region. Site-specific V_S^{30} values should be derived from actual in situ measurements as part of the geotechnical investigations.

TM 2.10.5 allows the use of the online USGS Java calculator to determine spectral ordinates for the 15% design level of the project. The USGS Java calculator provides the base (Site Class B) and site-modified (Site Class D) spectral ordinates. In accordance with TM 2.10.5, Site Class D site coefficients required by the ASCE 7-05 model were applied in the USGS Java Calculator to

the Site Class B spectral ordinates (S_s and S_1) to determine the site-modified spectral ordinates at 0.2 seconds (S_{ms}) and 1.0 second (S_{m1}) for all segments along the HST alignment. The ASCE 7-05 model within the Java calculator utilizes 5% damping. Calculated spectral ordinates for Site Classes B and D are presented in Table 4.4-2. As anticipated based on proximity to regional faulting, the seismic design parameters increase toward the southern reaches of the F-B alignment where seismic activity is more pronounced and historical damage is documented.

Table 4.4-2
ASCE 7-05 Ground Motion Parameters (USGS 2002)

Subsection	Location	Long/Lat	Site Class B			Site Class D	
			PGA	S_S	S_1	S_{ms}	S_{m1}
A	Fresno	119.8W/36.79N	0.21	0.51	0.22	0.71	0.43
B	Rural North	119.75W/36.58N	0.25	0.58	0.24	0.78	0.46
C	Kings River crossing	119.61W/36.39N	0.25	0.59	0.25	0.78	0.47
D	Hanford station	119.59W/36.33N	0.25	0.6	0.26	0.79	0.48
E	Rural central	119.57W/36.13N	0.28	0.68	0.28	0.85	0.52
F	Tule River crossing	119.51W/36.03N	0.29	0.68	0.29	0.86	0.53
G	County Line	119.36W/35.79N	0.33	0.78	0.32	0.93	0.55
G/H	Phillips Road	119.33W/35.63N	0.39	0.90	.35	1.02	.60
H	Shafter	119.27W/35.50N	0.42	1.00	0.38	1.10	0.62
H/J	Hageman Road	119.15W/35.40N	0.46	1.11	0.41	1.17	0.65
J	Coffee Road	119.09W/35.37N	0.48	1.14	0.42	1.19	0.66
L	Oak Street	119.04W/35.37N	0.48	1.16	0.42	1.20	0.66
L	Oswell Road	118.95W/35.37N	0.50	1.19	0.42	1.22	0.67
L	Comanche Drive	118.84W/35.34N	0.54	1.29	0.46	1.29	0.71

In accordance with Section 6.2.1 of TM 2.10.5, the 15% Design MCE Spectra for Elevated Structures have been developed at various locations along the HST alignment. The following steps were implemented in developing these spectra:

- Develop the Probabilistic MCE spectral ordinates for Site Class B using the USGS Java Calculator using the ASCE standard per ASCE 7-05 § 11.4.1.
- Adjust the Probabilistic MCE spectral ordinates for Site Class D using the USGS Java Calculator and construct the Adjusted Probabilistic MCE response spectrum per ASCE 7-05 § 11.4.3.
- Develop the deterministic response spectra for characteristic earthquakes of the capable faults using the online Caltrans ARS tool, Caltrans Deterministic Response Spectrum spreadsheet, and the Caltrans 2007 Fault Data Base and increase the calculated values by 150% per ASCE 7-05 § 21.2.2 (2007c).

- Develop the Deterministic MCE response spectrum by comparing the site-specific deterministic response spectra for capable faults to the Deterministic Lower Limit (DLL) response spectrum per ASCE 7-05 § 21.2.2.

- Compare the deterministic and probabilistic response spectra and select the lesser of these two spectra as the governing MCE response spectrum in accordance with ASCE 7-05 § 21.2.3.

- Apply the Elevated Structures Importance Factor of 1.25 to the MCE response spectrum to develop the 15% Design MCE Spectra for each alignment segment per TM 2.10.5 § 6.2.1.

Figure 4.4-1 through Figure 4.4-3 show the results of steps 1 through 5 of this process for Fresno, Tule River, and Bakersfield. With reference to Figure 4.4-1 and Figure 4.4-2, it is evident that the fault-specific deterministic response spectra are much lower than the Deterministic LL curve. Accordingly, the Deterministic LL governs the deterministic analyses at these two locations. With regard to Figure 4.4-3, neither the Oil Field Fault Zone nor the Kern Front Fault appear in the Caltrans 2007 Fault Database but do appear on the 1996 Caltrans Seismic Hazard Map. The response spectra for these faults were determined in accordance with the recommendations in the 2009 Caltrans Geotechnical Services Design Manual (V1.0). Figure 4.4-3 shows that the Oil Field Fault Zone yields deterministic spectra that exceed the DLL. Thus, the Deterministic MCE spectra for Bakersfield are a hybrid of the maxima of these two curves.

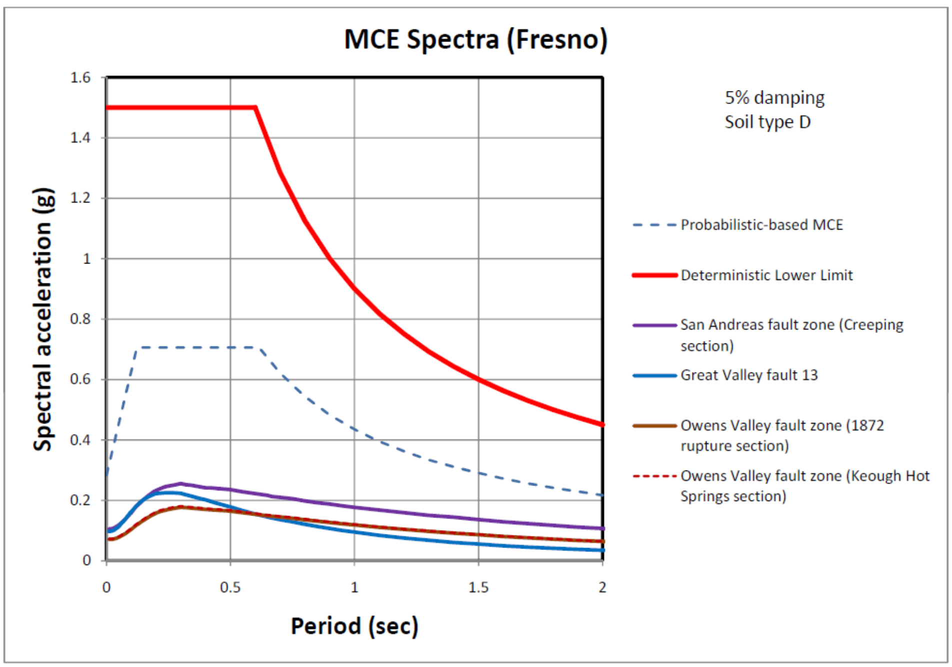

Figure 4.4-1
MCE Spectral Analysis: Fresno

04/02/2014 - RFP No.: HSR13-57

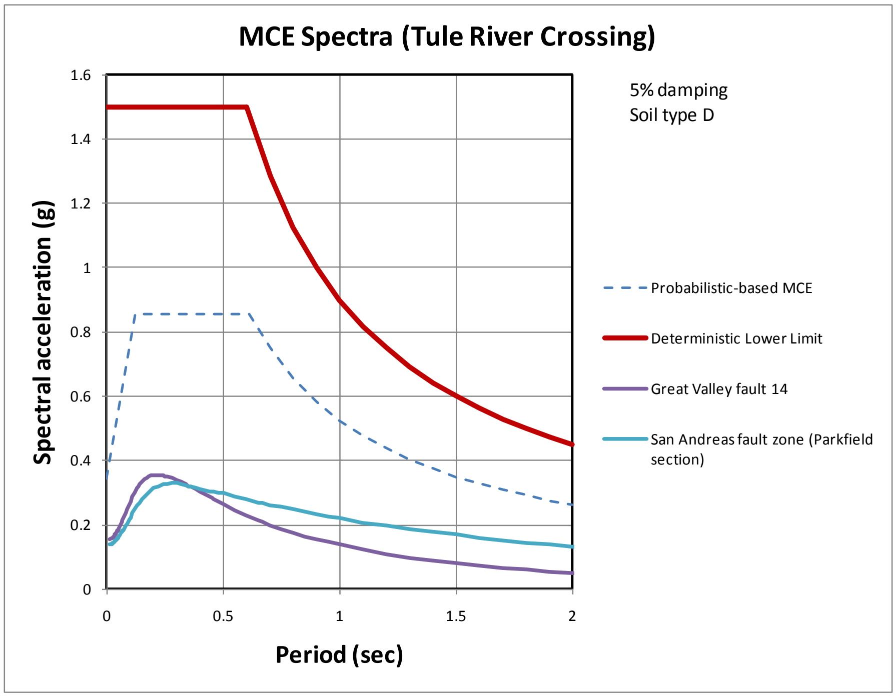

Figure 4.4-2
MCE Spectral Analysis: Tule River Crossing

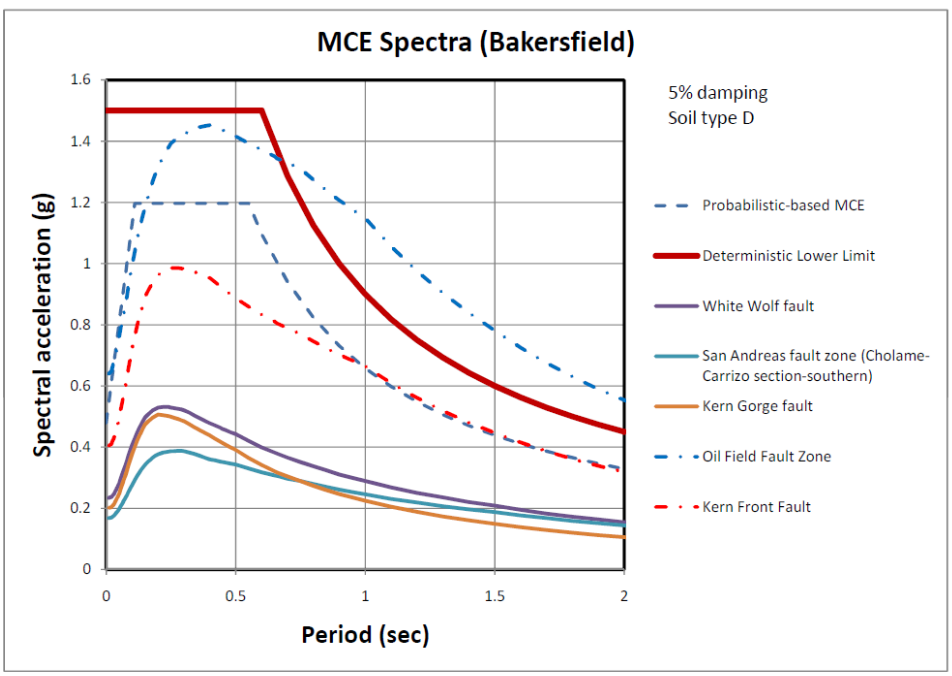

Figure 4.4-3
MCE Spectral Analysis: Bakersfield

04/02/2014 - RFP No.: HSR13-57

According to ASCE 7-05 § 21.2.3 (Step 5), the Deterministic MCE is compared with the Probabilistic MCE curve and *the lesser curve* is selected as the site-specific MCE spectral response acceleration. Based on the results, the Probabilistic MCE spectra govern for all three sites evaluated. Accordingly, Figure 4.4-4 shows the 15% Design MCE Spectra for Elevated Structures for all segments in the study area determined by multiplying the ASCE 7-05 Probabilistic MCE response spectrum at each segment by the Importance Factor of 1.25 (Step 6).

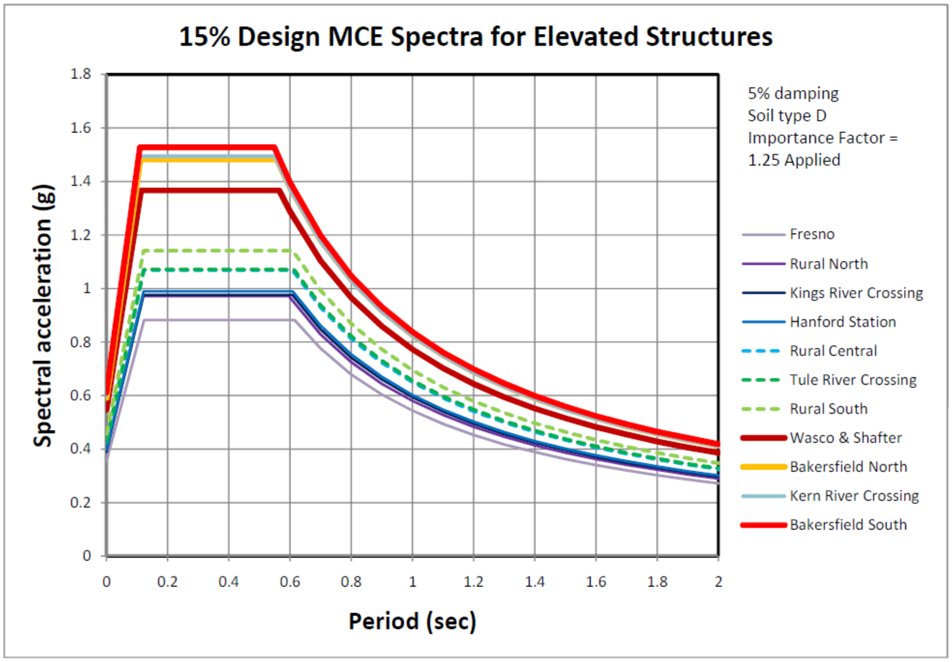

Figure 4.4-4
15% Design MCE Spectra: Elevated Structures

4.5 Seismically Induced Ground Deformation

Seismic ground deformations include liquefaction, lateral spreading, and seismic settlements. In accordance with TM 2.9.3, sites subject to liquefaction or lateral spreading are identified using the screening procedures described in SP 117 (CGS 2008) and also as clarified in SCEC's (1999) "Recommended Procedures for Implementation of SP 117 Guidelines for Analyzing and Mitigating Liquefaction Hazard in California." These two guidelines generally require a conservative assessment of portions of the CHSTP that coincide with areas of present and/or future potential groundwater within 50 feet of the ground surface and the presence of Holocene deposits. Figure A2 of Appendix A suggests that apart from the southern half of Segment H, the predominance of the alignment resides in Holocene deposits.

According to the SCEC (1999), the following screening criteria may be applied to determine if further quantitative evaluation of liquefaction hazard potential is not required:

- If the estimated maximum past, current, and future groundwater levels (i.e., the highest groundwater level applicable for liquefaction analyses) are determined to be deeper than 50 feet below the existing ground surface or proposed finished grade (whichever is deeper), liquefaction assessments are not required.
- If "bedrock" or similar lithified formational material underlies the site, those materials need not be considered liquefiable and no analysis of their liquefaction potential is necessary.

- If the corrected standard penetration blow count, $(N_1)_{60}$, is greater than or equal to 30 in all samples with a sufficient number of tests, liquefaction assessments are not required. If CPT soundings are made, the corrected CPT tip resistance, qc1N, should be greater than or equal to 160 in all soundings in sand materials.
- If clayey soil materials are encountered during site exploration, those materials may be considered non-liquefiable. For purposes of this screening, clayey soils are those that have a clay content (particle size <0.005 mm) greater than 15%. However, based on the so-called "Chinese Criteria," clayey soils having all of the following characteristics may be susceptible to severe strength loss:
  - Percent finer than 0.005 mm less than 15%.
  - Liquid Limit less than 35.
  - Water Content greater than 90% of the Liquid Limit.

The following sections provide preliminary assessments of risk of encountering these conditions along the alignment. However, the existing geotechnical database is insufficient to provide reliable quantitative assessments.

4.5.1 Liquefaction

Site susceptibility to liquefaction is a function of depth, density, and groundwater level, in addition to the magnitude of the earthquakes. One of the most damaging effects of ground shaking is a phenomenon known as liquefaction. Soil liquefaction refers to the loss of shear strength in granular soils due to an increase in pore pressure during dynamic (monotonic, cyclic, or shock) loading (Rauch 1997). When loose, saturated soils are sheared, the soil grains have the tendency to rearrange in a more densely packed structure, thereby forcing water out from the pore spaces. Impedance of pore water drainage leads to a progressive increase in pore water pressures with shear loading (Rauch 1997). The subsequent transfer of stress from the soil skeleton to the pore water leads to a decrease in the effective stress and shear resistance of the soil. Liquefaction-related phenomena can include lateral spreading, ground oscillation, flow failure, loss of bearing and other shear strength related engineering parameters, subsidence, and buoyancy impacts.

Liquefaction is most commonly associated with shallow, loose, saturated deposits of cohesionless soils subjected to strong earthquake shaking. Traditionally, a depth of 50 feet (about 15 meters) has been used as the depth of analysis for the evaluation of liquefaction (SCEC 1999). While liquefaction hazards are most severe in the upper 50 feet of the surface, liquefaction potential should be considered at greater depths where slopes near a free face occur or where deep foundations go beyond that depth (CGS SP 117 2008). Soils above the historical or predicted future groundwater table (i.e., soils that are not saturated) will not liquefy. Consideration should also be given to locally saturated zones or where perched groundwater may be prevalent during the design life (CGS SP 117 2008).

Threshold PGA

Review of USGS hazard maps does not indicate the presence of potential liquefaction zones along the FB Section. However, these maps are based upon historical occurrences of liquefaction and do not include detailed mapping outside of the San Francisco Bay Area and the greater Los Angeles area. While regional studies (in the San Francisco area) have shown liquefaction can occur at PGAs of less than 0.1g for hydraulically placed artificial fills, studies in the SJV have shown that the PGA must approach 0.3g before liquefaction occurs in sandy soils with relative densities typical of the San Joaquin alluvial deposits (Fresno County 2000 and Tulare County 2008).

As noted in Section 4.4, probabilistic PGAs north of the Tule River crossing are anticipated to be between 0.21g to 0.29g at the bedrock level. South of Corcoran, PGAs range between 0.29g and 0.54g. According to the USGS Deaggregation Calculator these values could increase by 30% for the Site Class D. Therefore, PGAs at the ground surface could exceed 0.3g throughout most of the alignment. This indicates that liquefaction could occur provided other screening criteria noted above are satisfied. Additional geotechnical investigations are required to determine the location and extent of potentially liquefiable zones.

Shallow Groundwater

The screening criteria define shallow groundwater as within 50 feet of the ground surface or finished grade. Figure 4.5-1 shows areas where shallow groundwater is known to exist or has been recorded in the recent past. The purple shaded areas in this figure have been developed based on a variety of sources including Figure A6 of Appendix A and Figure 3.7-4. Other sources such as the KMHP (2005) and the Draft Kings County General Plan (2009) suggest that zones of persistent shallow groundwater and liquefaction susceptibility occur over much broader areas south and west of the proposed alignment. Within Tulare County, between Corcoran and the Tulare/Kern County line, groundwater studies indicate shallow groundwater may exist within 50 feet of the ground surface along the alignment (Quinn 2007). Areas shaded in blue depict the limits of shallow groundwater identified in 2000 (USGS PP 1766 2009) when groundwater table levels peaked prior to their most recent decline. The blue shaded area was verified against hydrographs of wells within 1 mile of the alignment obtained from the CDWR Water Data Library.

At Subsection FB-K (Kern River Crossing), areas of persistent high groundwater are also likely to exist due to persistent discharge from Lake Isabella Dam mandated by the USACE. Similarly, high groundwater tables should be anticipated at other river crossings along the alignment. By comparison to Figure 5.5-3, zones of shallow groundwater potentially affecting Subsections FB-E, F and G are in agreement with the historical limits of the Tulare Lake bed. Additional information regarding the depths to shallow groundwater during various periods along the alignment is shown on Table 3.7-4.

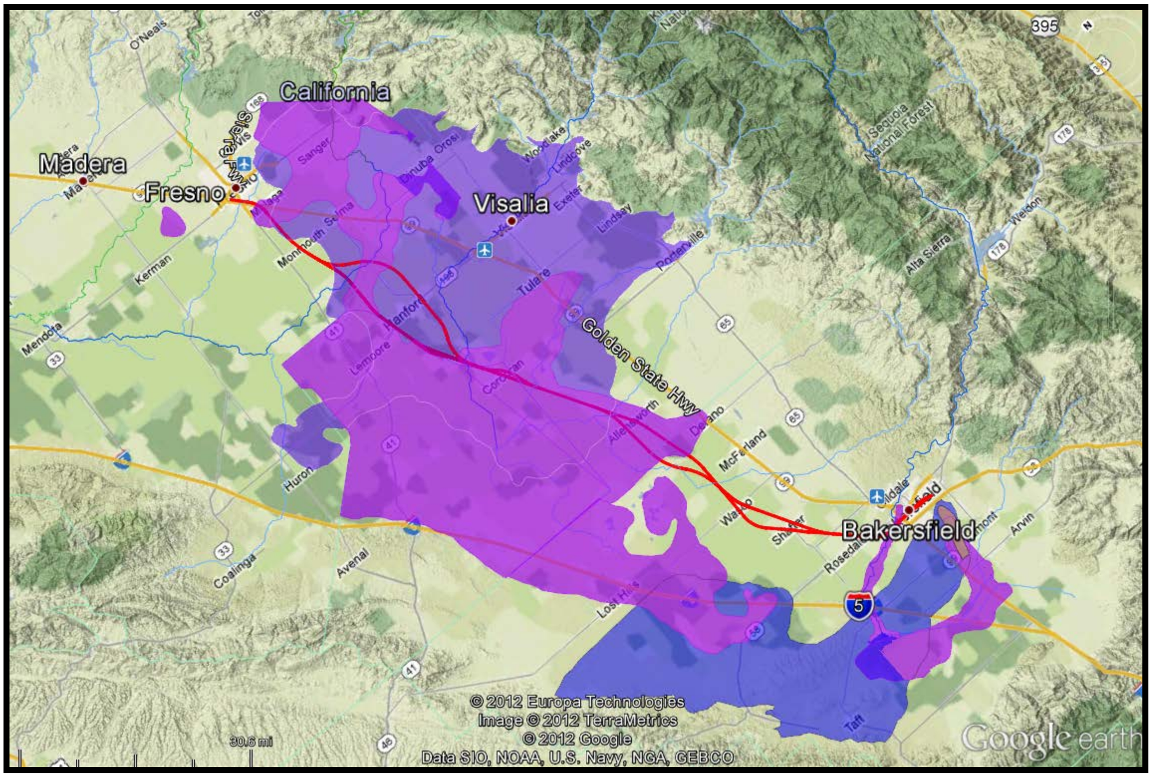

Figure 4.5-1
Shallow Groundwater (less than 50 feet deep)

Cyclic Stress Ratio

Analytical evaluation of liquefaction potential is traditionally based on the pioneering work by Seed and Idriss (1971). The “simplified procedure” originally developed involves the calculation of the factor of safety obtained by determining the Cyclic Resistance Ratio (CRR) and Cyclic Stress Ratio (CSR) of the site soils. The deterministic methods proposed by Seed and Idriss have been modified and improved by several researchers to include probabilistic analysis methods over the years. Conventionally, liquefaction susceptibility is empirically correlated to the CRR and the CSR through either the corrected SPT ($N_{1,60}$) or the corrected cone penetrometer tip resistance q_{c1N} (SCEC 1999). Although available historical data are sparse and there are large uncertainties associated with their measurement, they are considered representative and suitable for use for preliminary assessment of the liquefaction potential along the alignment but are not considered sufficiently specific for preliminary design purposes.

For the purpose of this study, the Cetin et al. (2004) methodology, which is based on the Seed et al. (2003), was implemented in accordance with CGS SP 117. For comparison purposes and to account for uncertainty with regard to perched water conditions and seasonal variations, the groundwater table was conservatively assumed to be at 10 feet below the ground surface at all locations. This assumption will be refined at the 30% design stage once the proposed GI is complete.

04/02/2014 - RFP No.: HSR13-57

Two levels of ground shaking were considered in the preliminary liquefaction potential assessment. The parameters of the characteristic earthquakes at each segment were derived using the deaggregation diagrams prepared using the USGS Deaggregation Calculator (2002 edition). In order to investigate the effect of M_w, both short and long period deaggregation plots were derived for the periods of zero (PGA) and 1.0 second, respectively. Table 4.5-1 shows the results of these analyses and the grouping utilized to achieve the 20% special ground motion variability required by TM 2.9.6. Lower Limit M_w (LLM_w) represent the short period, PGA deaggregation plots. Upper Limit M_w (ULM_w) represent longer period, 1.0 second deaggregation plots.

Table 4.5-1
Preliminary Modal Moment Magnitudes (USGS 2002)

Segment Group No.	Segment Name	Modal M_W LLM_w/ULM_w	15% Design M_W LLM_w/ULM_w
1	Fresno	5.2/7.85	5.2 /7.85
	Rural North	5.2/7.84	
	Kings River Crossing	5.2/7.83	
	Hanford Station	5.2/7.82	
2	Rural Central	5.2/7.83	6.4 /7.85
	Tule River Crossing	5.2/7.82	
	Rural South	6.4/7.85	
3	Wasco & Shafter	6.4/7.84	6.6 /7.84
	Bakersfield North	6.4/7.81	
	Kern River Crossing	6.6/7.81	
	Bakersfield South	6.4/7.83	

LLM_w: Lower Limit moment magnitude
ULM_w: Upper Limit moment magnitude

04/02/2014 - RFP No.: HSR13-57

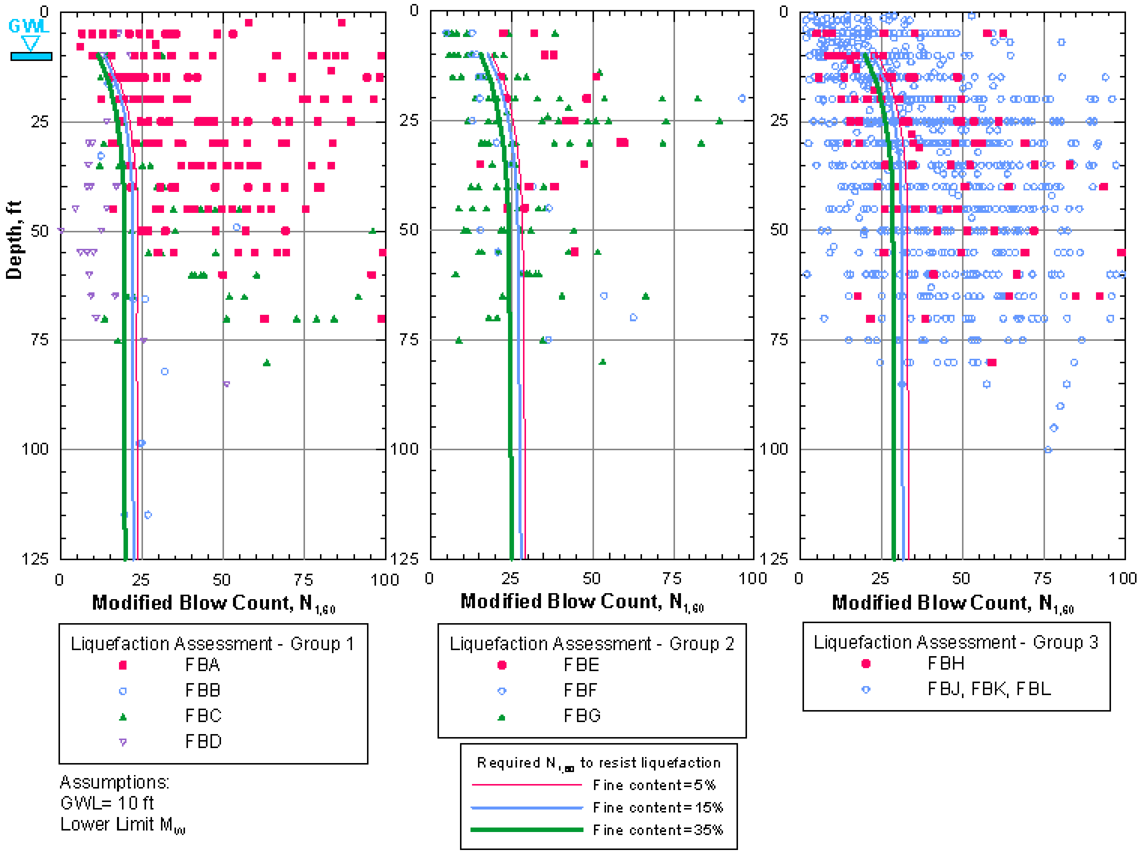

Figure 4.5-2
Preliminary Liquefaction Evaluation: Lower Limit M_w

04/02/2014 - RFP No.: HSR13-57

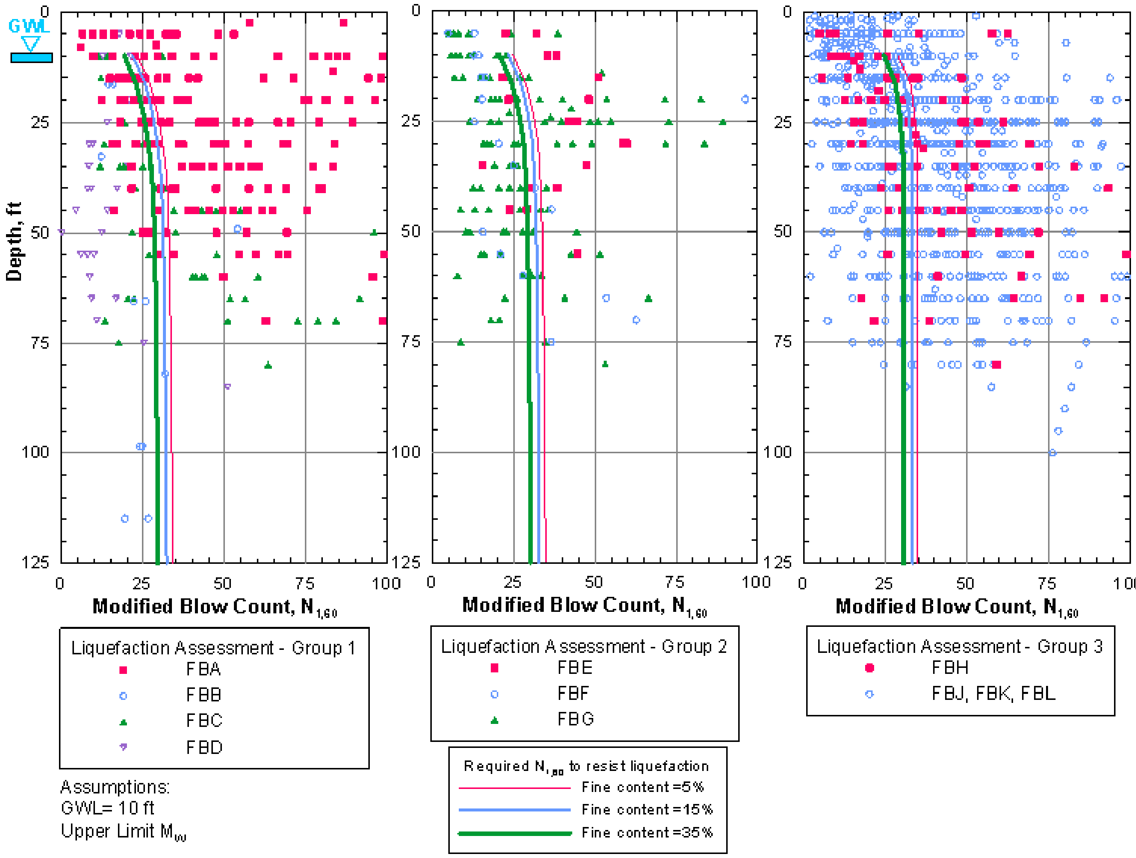

Figure 4.5-3
Preliminary Liquefaction Evaluation: Upper Limit M_w

Figure 4.5-2 and Figure 4.5-3 show the results of the preliminary liquefaction evaluation for all subsections along the alignment. Liquefaction triggering curves were calculated for different fine contents (i.e., 5%, 15%, 35%) However, the results illustrate that fines content does not have a significant effect on the liquefaction susceptibility. It is, however, understood that soils with higher fines content generally are less susceptible to liquefaction. Points that fall to the right of the triggering curves would not be susceptible to liquefaction. Likewise, points that fall to the left are susceptible to liquefaction.

The assumptions made in this analysis are deliberately conservative and show that under worst-case scenarios liquefaction susceptibility cannot be ruled out. Therefore, insofar as the study area is concerned, a risk descriptor of “low” is inappropriate. While there are reports of instances of seiches, fissuring, sand boils, and hydrologic changes from Sacramento to the Colorado River delta associated with the Fort Tejon earthquake, the historical data are inadequate in quantity and quality, so a risk descriptor “high” is equally inappropriate. Until site specific, high-quality density results and ground motion investigations become available, the liquefaction hazard throughout the alignment should be considered moderate. In cases where the liquefaction hazard is identified, efforts should be made to reduce the damage effects. For embankments, the most widely used mitigation strategies include soil densification and pore water pressure dissipation systems. For structures such as walls and viaducts, foundation systems are typically extended deeper and/or are stiffened to account for the associated strength loss and downdrag loads.

Recent Evaluations by Others

Within Subsection FB-K several recent liquefaction studies associated with construction of the Westside Parkway in Bakersfield were provided for this desk study. Liquefaction analyses conducted by Dokken (2008) at the Mohawk Street Interchange concluded the following:

> The result of the liquefaction analysis shows there is a low chance of global liquefaction (liquefying of all of the site soils) occurring at the site. However, localized liquefaction in discrete soil layers has been identified in soils encountered in the borings drilled throughout the site.

Adjacent to Dokken's project, between Mohawk Street and Coffee Street (within FB-K), Kleinfelder's (2008a) analysis of soils reaches an entirely opposite conclusion suggesting the following:

> Based on the relative density of the site soils, groundwater conditions and the design PHGA, evaluation based on Youd et al. (2001), indicates anticipated cyclic stress from a major event on the Kern Front Fault is not likely sufficient to result in liquefaction or associated seismically induced settlement or bearing loss.

Review of USGS hazard maps does not indicate the presence of potential liquefaction zones along the FB Section. However, these maps are based upon historical occurrences of liquefaction and do not include detailed mapping outside of the San Francisco Bay Area and the greater Los Angeles area. While available USGS hazard maps do not identify the HST alignment as a potential liquefaction zone, a site-specific site investigation is required to evaluate the level of liquefaction hazard along the HST alignment, based on local soil and groundwater conditions. CGS guidelines recommend correlation and analyses based on SPT and CPT data to quantitatively evaluate liquefaction resistance.

4.5.2 Lateral Spreading

When liquefaction occurs on sloped or free-face ground conditions, a deformation failure known as lateral spreading may occur. Lateral spreading is defined as a lateral translation of gradually sloping land as result of a buildup of pore pressures or liquefaction in a shallow deposit during an earthquake (Rauch 1997). Lateral spreading may occur on slopes of 0.3 to 5% underlain by loose sands and a shallow water table (Bartlett and Youd 1992). These deformation failures often begin with lateral movement and ground surface cracks at the toe of a slope that move progressively upslope as slope movement develops (Kramer 1996).

No specific published data are available concerning lateral spreading near the northern reaches of the FB Section. However, because areas with streams or rivers in recent alluvial deposits are more conducive to lateral spreading (Youd and Hoose 1976), the potential for lateral spreading does exist along sections of the HST alignment that traverse over steep-sided river channels such as Kings River, Kaweah River, and Tule River.

Lateral spreading within Subsection FB-K at the Kern River Crossing was evaluated by Dokken (2008):

> The chance of a seismically induced lateral spread is also low as the liquefiable layers are at a depth (greater than 20 feet below existing grade) and when combined with the essentially flat topography of the project site, no free face exits which is required to trigger lateral spreading.

During the design stage, consideration should be given to ensure that the earthworks are not or do not become susceptible to lateral spreading. Appropriate mitigation measures should be employed to improve soil strength and limit soil displacement where the potential for lateral spreading is identified. In this regard, soil improvement techniques are widely applied in the engineering practice to restrict the extent of lateral spreading. For example, Figure 4.5-4 illustrates the basic strategy for liquefaction and lateral spreading remediation using the soil improvement methods.

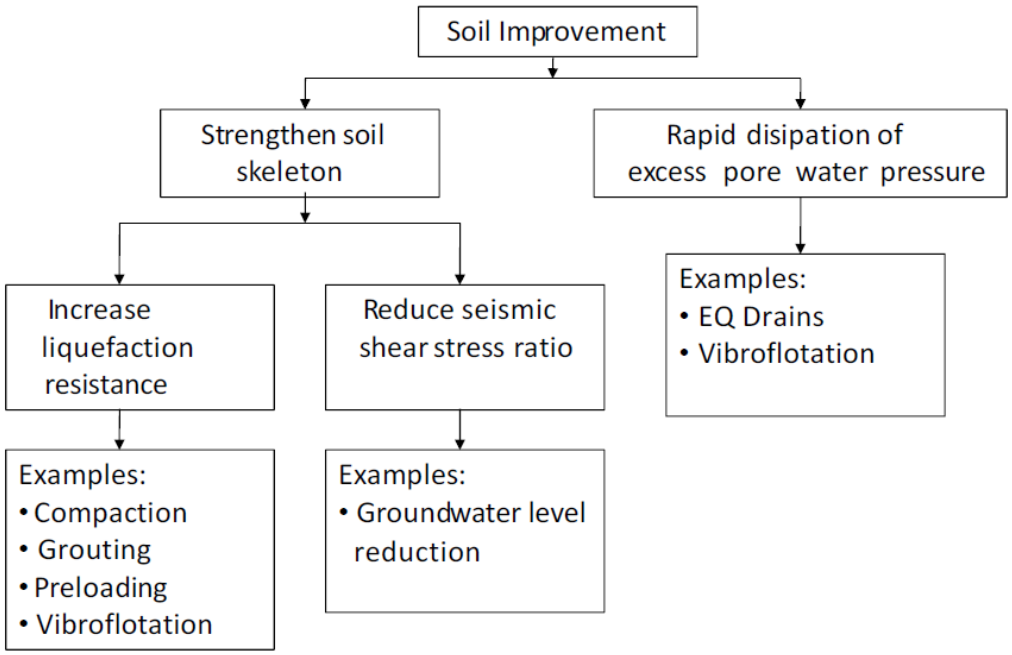

Figure 4.5-4
Liquefaction and Lateral Spreading Remediation Strategies

No alignment-specific topographic survey currently exists to more clearly define the location of potential lateral spreading. A site-specific geotechnical investigation, including SPTs and CPTs, is necessary to evaluate in situ soil type, relative density, particle size gradation, and other properties associated with lateral spreading. Accurate information on groundwater table elevations is critical in the lateral spreading prediction. Accordingly, the geotechnical investigation should include a long-term, groundwater table monitoring component to record seasonal fluctuations.

4.5.3 Seismically Induced Settlement

Strong ground shaking may also induce ground surface settlement. Granular soils are particularly susceptible to seismically induced settlement via densification and rapid compaction during to earthquake loading (seismic compaction). The post-earthquake densification of saturated sand is a function of grain size and density, the maximum seismically induced shear strain, and the amount of excess pore pressure generation (Lee 2007). Seismically induced differential settlement, a localized loss of support under the footprint or across the span of a structure, is common at sites with interbedded alluvial deposits (CGS SP 117 2008). While it is difficult to predict seismically induced differential settlement, localized differential settlements of up to two-thirds of the overall predicted settlements may be estimated (CGS SP 117 2008).

Ground deformations in compacted fill slopes related to seismic compaction have been well documented in the literature (Pyke et al. 1975, Stewart et al. 2001), and are recognized as representing a significant hazard with respect to collateral loss during earthquakes. Accordingly, the estimation of ground settlements from seismic compression is becoming a common component of geotechnical seismic design practice for hillside areas in the mountainous areas of Southern California.

The current state of practice for estimating the seismic compaction of unsaturated compacted fill soils consists of the methodology presented by Tokimatsu and Seed (1987), which is strictly applicable to only clean sands. Stewart et al. (2003) have developed an updated procedure to account for fines content. Partial motivation for this update comes from laboratory testing by Stewart et al. (2002), which has shown that clean sands can experience up to 10 times more vertical strain than soils with fines compacted to a comparable density. Consequently, current methods for estimating seismic compaction may be overly conservative and may not be applicable to soils containing fines. The procedure developed by Stewart et al. (2003) decouples the calculations of shear strain and volumetric strain, and utilizes recent research results on stress reduction factors (r_d), soil modulus reduction curves, and soil volumetric strain models. The results are generally found to compare favorably to observations, although problems in shear strain estimation are encountered for very strong levels of shaking (PGA > 1g).

Limited published data are available concerning seismically induced settlement near the FB Section. There are brief descriptions of up to 30 inches of settlement that occurred in some embankments along Highway 58 to the east of the study area due to the 1952 Kern County earthquake. The KHMP states that *extensive releveling of farmlands* in the M-T Sub-basin was necessary following the 1952 Kern County event.

With regard to the investigation in the vicinity of Subsection FB-K, Dokken (2008) notes the following:

> However, the site is anticipated to experience dry dynamically induced settlements on the order of 1 to 2 inches where the new profile matches closely (1 to 2 feet) to original ground. This is due to the loose silty sand layer which was encountered in the borings throughout the site ranging in thickness from 8 to 15 feet as measured from original ground.

Adjacent to Dokken's project, between Mohawk Street and Coffee Street (within Subsection FB-K), Kleinfelder's (2008a) analysis of soils suggests the following:

> The subsurface conditions encountered in the borings advanced at the site are not generally considered conducive to such seismically induced ground deformation. Based on Tokimatsu and Seed (1987), it is estimated about 0.1 inch of total settlement due to dynamic compaction would occur along the alignment during an earthquake.

Typically, areas underlain by unconsolidated alluvial sediments and improperly engineered construction fills are most susceptible to seismically induced settlement. Conditions triggered by earthquakes that may cause settlement of structures founded on these soils include liquefaction, volumetric compression, or dynamic structural loads that cause rocking (Day 2006). The amount of differential and total settlement associated with seismic compaction in any areas where significant fills or embankments are proposed should be evaluated according to the methods proposed by Stewart et al. (2003) and Tokimatsu and Seed (1987) once the fill depths and embankment geometries are known and site-specific data regarding the ground characteristics are gathered through a geotechnical investigation.

4.6 Seismically Induced Slope Instability

In areas with steeper sloping terrain, strong ground shaking may be accompanied by slope instability or landslides. Seismically induced landslides occur as a result of the downward and outward movement of masses of loosened soil, rock, and vegetation under gravitational forces. Landslide susceptibility depends, in part, on slope steepness, material type and properties, water content, and amount and type of vegetation. Landslides may be in the form of fast-moving debris flows or slow-moving soil creep.

Along the alignment, the SJV consists of relatively flat (low relief) terrain that does not contain the requisite topographic and/or geomorphological features to produce a significant landslide hazard. The lack of steep slopes close to the HST alignment make seismically induced landslides or debris flows low potential hazards. Still, there is a potential for localized small slides and minor slumps where the HST alignment crosses steeper river banks and creeks or man-made features. Structures located at the top or toe of slopes, such as road embankments or bridge abutments near river banks, are most likely to experience damage as a result of seismically induced slope instability.

The RC has reviewed hazard mitigation plans and topographic maps for all counties along the alignment to identify areas near the FB Section that may be susceptible to slope instability following an earthquake. Review of the Fresno County MHMP indicates areas in the foothill and mountain regions of the county where relatively steep slopes and unconsolidated, weathered soils are susceptible to instability. According to the Kings County MHMP, the only significant landslide hazard exists in the southwestern area of the county, including Kettleman Hills, where steeper slopes are present approximately 25 miles to the east of the proposed alignment.

Slopes subject to failure within the Bakersfield area are predominantly found along the river terraces, bluffs, and foothills to the northeast and east of the city. Investigations to date have documented two landslides in the foothills northeast of the city in the vicinity of the Kern River State Park about 6.5 miles due north of the town of Edison. Only limited exposure to landslides is predicted for the urban areas of Bakersfield due to constraints on slope-side development. Some construction, however, on sloping terrain could inadvertently trigger landslides unless appropriate precautions are utilized on a site-specific basis.

Steep sided valleys with high relief terrain, such as in the Sierra Nevada, are potentially at risk from slope instability. Although run-out from these landslides is not likely to directly affect the alignment, run out into a reservoir or lake could have an effect downstream on the proposed alignment in the form of a seiche. This subject is discussed in more detail in Section 4.7.2 below. A review of the CGS Index to Landslide Maps has no coverage for the areas pertinent to the FB Section.

Apart from areas in close proximity to riverbeds, these types of geologic terrains do not exist in the relatively flat-lying, urbanized and agricultural areas within the study area thus the hazard potential is considered low. A site-specific GI, including SPTs and CPTs, is necessary to evaluate in situ soil type, strength, relative density, water content, organic matter, and other properties related to slope stability at the noted areas of concern.

4.7 Seismically Induced Flooding

4.7.1 Dam Inundation

Flooding may be caused by the catastrophic failure of a water-retaining structure, such as a dam or levee, following an earthquake. Dam inundation maps are available for major reservoirs and are commonly included in hazard mitigation plans for local jurisdictions. Dam inundations maps

reviewed from various county hazard mitigation plans indicate that the FB Section crosses potential inundation areas of several reservoirs including Terminus Dam, Success Dam, and the auxiliary dam at Lake Isabella. These inundation areas relative to the HST alignment are shown on Figure A19 of Appendix A.

According to the Fresno County MHMP (2008), there are several hundred dams in Fresno County constructed for flood control, irrigation storage, electrical generation, recreation, and stock watering purposes. Twenty-three dams present a significant safety risk to downstream populations if one or more were to fail (Fresno County MHMP 2008). Failure of the Redbank, Fancher Creek, and Redbank detention dams located approximately 8 miles east of the proposed Fresno Station would result in flood waters traveling westerly through Fancher Creek, which meanders to the northwest of Calwa City (F-B CHSTP SGGR 2010). Flood waters would likely inundate portions of the Subsection FB–A alignment from the proposed Fresno Station south to Calwa City.

Pine Flat Reservoir is located approximately 27 miles to the northeast of the HST alignment within the Kings River drainage area (F-B CHSTP SGGR 2010). The Pine Flat Dam, located near Piedra, is a 440-foot concrete gravity dam operated by the USACE. Failure of the Pine Flat Dam would cause flooding south and southwest through the Kings River drainage area. The inundation area would intercept the Segments FB–B, FB–C, FB–D, and FB–E alignment about 2.5 miles north of Bowles and would continue to spread to the south to an area east of Hanford (F-B CHSTP SGGR 2010).

Lake Success is located approximately 37 miles to the east of Corcoran and about 34 miles east of the Tule River Crossing at the northern most terminus of the study area. The dam consists of a 156-foot-high earth dam and impounds approximately 62,000 acre-feet of water. The primary purpose of the dam is flood control. According to the Tulare County General Plan, failure of the Success Dam could cause substantial flooding in Tulare County; however, a comprehensive analysis of potential dam failure has not been evaluated. According to the Kings County General Plan and the USACE, the failure of Success Dam would not affect portions of Kings County.

Terminus Reservoir (Lake Kaweah) is located approximately 37 miles to the east of the proposed HST Hanford Station (F-B CHSTP SGGR 2010). According to the Tulare County General Plan (2004), if the Terminus Dam failed at full capacity, flood waters would be expected to reach portions of Kings County within 12 hours. It is predicted that flooding would cover an approximately 6-mile portion of the HST alignment between Hanford and Corcoran (F-B CHSTP SGGR 2010).

Isabella Dam is located approximately 37 miles to the northeast of Bakersfield, California. The facility consists of a main dam built and operated by the USACE and an auxiliary dam, which is part of the Borel Hydroelectric project. The main dam is 98 feet high, is of earthen construction, and serves primarily for flood control; it impounds about 568,000 acre-feet of water. The water impounded behind the main dam forms Lake Isabella. Water from the lake is diverted in three ways: release into the Lower Kern River and diversion through the hydroelectric project either via the main dam or auxiliary dam. In late April 2006, seepage problems were discovered in the Isabella Auxiliary Dam. In 2007, the USACE found evidence of an active fault (Kern Canyon Fault) beneath the structure. Upon discovery, the USACE reduced the fill capacity to no more than 66%, a level deemed within acceptable safety parameters. Updated flood maps prepared by the USACE in 2008 show that southern portions of the Rural Segment HST west of Bakersfield could be inundated by as much as 20 feet of water if Isabella Dam were to fail. Officials from Kern County and the USACE continue to study and monitor the dam. Up to 20 feet of the auxiliary dam's foundation have been determined to be susceptible to liquefaction. If an earthquake were to occur in the vicinity of the Kern Front Fault, it could result in a break in the dam (HydroWorld.com 2007). Under certain conditions this could cause the entire lake storage to be

released, which would result in flooding 60 square miles of metropolitan Bakersfield and the surrounding areas of Oildale and Greenacres. The likelihood of the dam failing entirely, with the lake at capacity, was estimated at 1 day in 10,000 years or 1:3,650,000 (KMHP 2005).

The inundation areas shown on Figure A19 of Appendix A are conservative scenarios, assuming catastrophic failure of dams and other water-retaining structures while at maximum capacity (F-B CHSTP SGGR 2010). Apart from the conditions at the Isabella Dam, the potential earthquake magnitudes and ground shaking intensities anticipated near the FB Section are not likely to produce a seismic event that could induce catastrophic dam failure.

Hydrology, Hydraulics, Drainage, Stormwater and Floodplain impact reports have been prepared separately to this report.

4.7.2 Seiche

Seiches are standing waves created in an enclosed body of water such as a lake, river, or reservoir due to a seismic event. Seiches may occur from the rapid displacement of large amounts of water due to strong seismic oscillation. The period of oscillation depends on the size of the water body and the magnitude of the oscillation. Seiche oscillations may last for minutes to several hours, and have been recorded to cause significant damage to nearby structures, including dams, shoreline facilities, and levees or embankments (F-B CHSTP SGGR 2010). In addition, landslides into water can also create Seiche.

There are reports that the 1857 Fort Tejon earthquake produced seiches in Lake Tulare that stranded fish miles from the shore (KMHP 2005). Portions of the Kern River reportedly flowed upstream during this event, and the river overtopped its banks by 4 feet. Apart from the KMHP (2005), no specific published data are available concerning seiches near the FB Section. Since there are no longer any significant bodies of water within close proximity to the alignment able to produce potentially damaging waves other than at river crossings, seiches are considered a low potential hazard. The compound hazard of large bodies of climatic floodwater and seiches has not been explored as part of this study.

4.7.3 Tsunami

A tsunami is a series of ocean waves generated by sudden displacements in the sea floor, landslides, or volcanic activity (NOAA 2010). Tsunamis are commonly associated with submarine faults that displace water in the ocean over long distances (F-B CHSTP SGGR 2010). Due to the relatively large distance from the Pacific Ocean (about 75 to 100 miles), a tsunami does not present a potential hazard to the FB Section.

4.8 Future Probable Damage

The SCEC and the WGCEP (1995) have published a map displaying how often damaging (MMI VII) earthquakes are likely to occur in Southern California for a period of time between 1994 and 2024. Figure 4.8-1 presents the results of SCEC's hazard analyses in terms of average rates of earthquake shaking and probability of exceeding the threshold PGA of 0.2g (MMI VII) over a time frame of 100 years. This map suggests that most of the alignment within the study area falls within the probability of suffering one MMI VII (or greater) earthquake per century. This prediction is consistent with the 100-year historical recurrence of such ground shaking levels between the 1857 Fort Tejon and 1952 Kern County events, both of which produced MMI VII (or greater) intensities along the proposed alignment within the past 100 years.

This same information can be expressed in terms of probabilities of earthquake shaking. For instance, a place that averages one time of severe shaking each century has a probability of shaking in any one year of 1%, and in any 30 years of 26%. This analysis predicts that Southern

California should experience a magnitude 7.0 or greater earthquake about seven times each century. About half of these will be on the San Andreas fault "system" (i.e., the San Andreas, San Jacinto, Imperial, and Elsinore Faults), and half will be on other faults. The equivalent probability in the next 30 years is 85% (KMHP 2005).

Figure 4.8-1 shows the rate of shaking as if everywhere were on firm rock (Vs^{30} = 2500 ft/sec). This map does not include site effects. The tabulation of soil conditions for all of Southern California was not completed as of May 2001. SCEC has another project (Phase III) in progress that will update this map by showing a higher level of shaking for soft-soil sites. This will lead to a higher rate of damaging shaking because the more common smaller earthquakes will produce greater shaking in soft soil. The result will be to slightly increase the rates for the sedimentary basins such as the SJV where the alignment runs. Therefore it is likely that the future probable damage to the CHSTP will increase from that shown here.

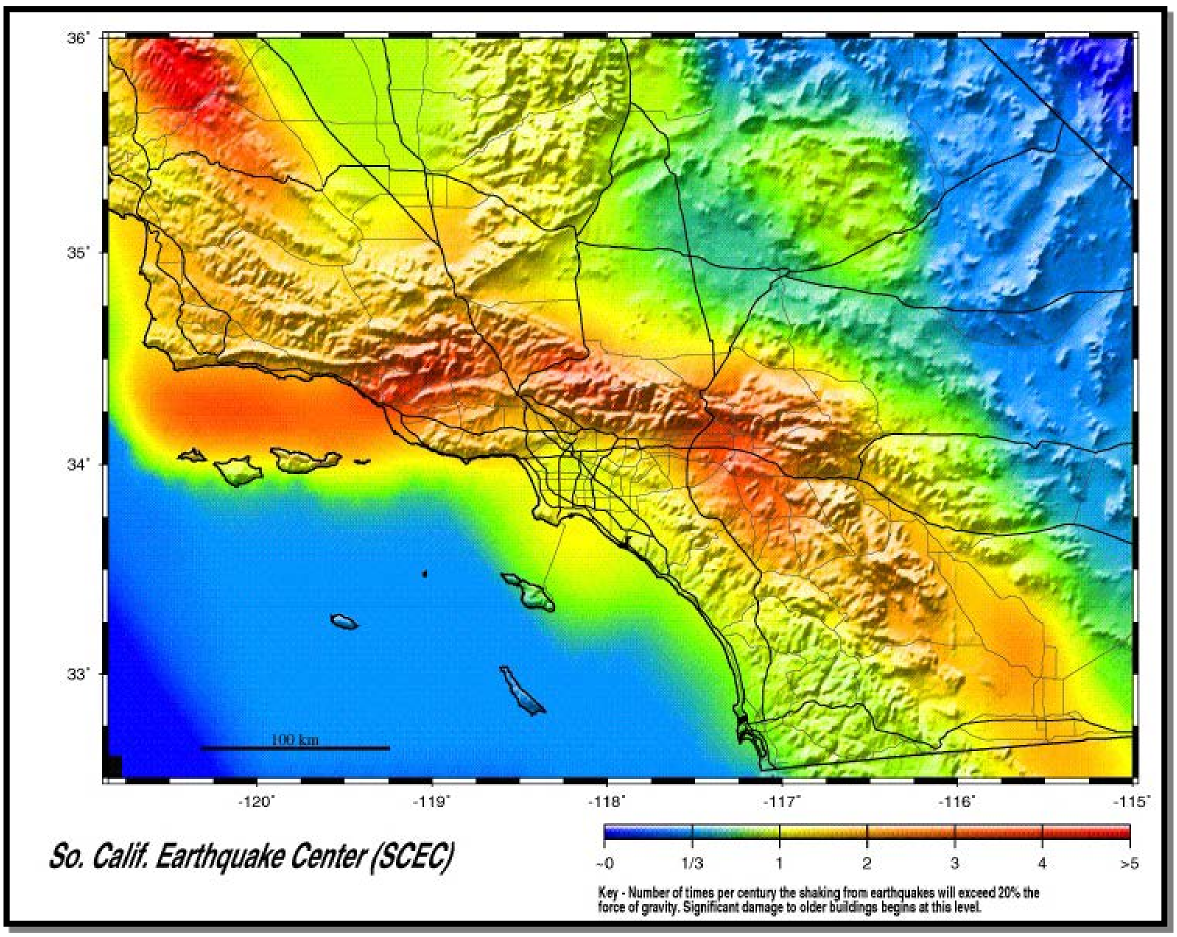

Figure 4.8-1
Future Probability of Damaging Earthquakes 1994–2024 (SCEC and WGCEP 1995)

04/02/2014 - RFP No.: HSR13-57

CALIFORNIA
High-Speed Rail Authority

Section 5.0

Geologic Hazards

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5.0 Geologic Hazards

5.1 Volcanic Hazards

Volcanoes are formed by an opening in the earth's crust that allows magma from within the upper mantle to flow to the surface. Volcanic eruptions may produce lava flows, lahars, debris flows, pyroclastic flows, ash deposits, and the release of gases that are hazardous to structures and people within the zone of influence, which can be as large as hundreds of miles.

Review of USGS hazard maps indicates that the primary volcanic hazard near the FB Section is from the Long Valley Caldera/Mono-Inyo Volcanic Field, located on the western edge of the Basin and Range Province along the base of the Sierra Nevada Range (Harden 2004). CGS also published SP 63 *Status of Volcanic Prediction and Emergency Response Capabilities in Volcanic Hazard Zones of California* (1982). This publication identifies eight zones of potential volcanic hazards across the state. Of these, only the Long Valley Caldera and the Golden Trout Creek volcanic field are in proximity to the study area. However, the Golden Trout Creek volcanic field does not appear to be a specific threat to the study area based on CGS SP 63. Figure 5.1-1 shows the location of the Long Valley Caldera and the Golden Trout Creek Volcanic Field relative to the proposed alignment.

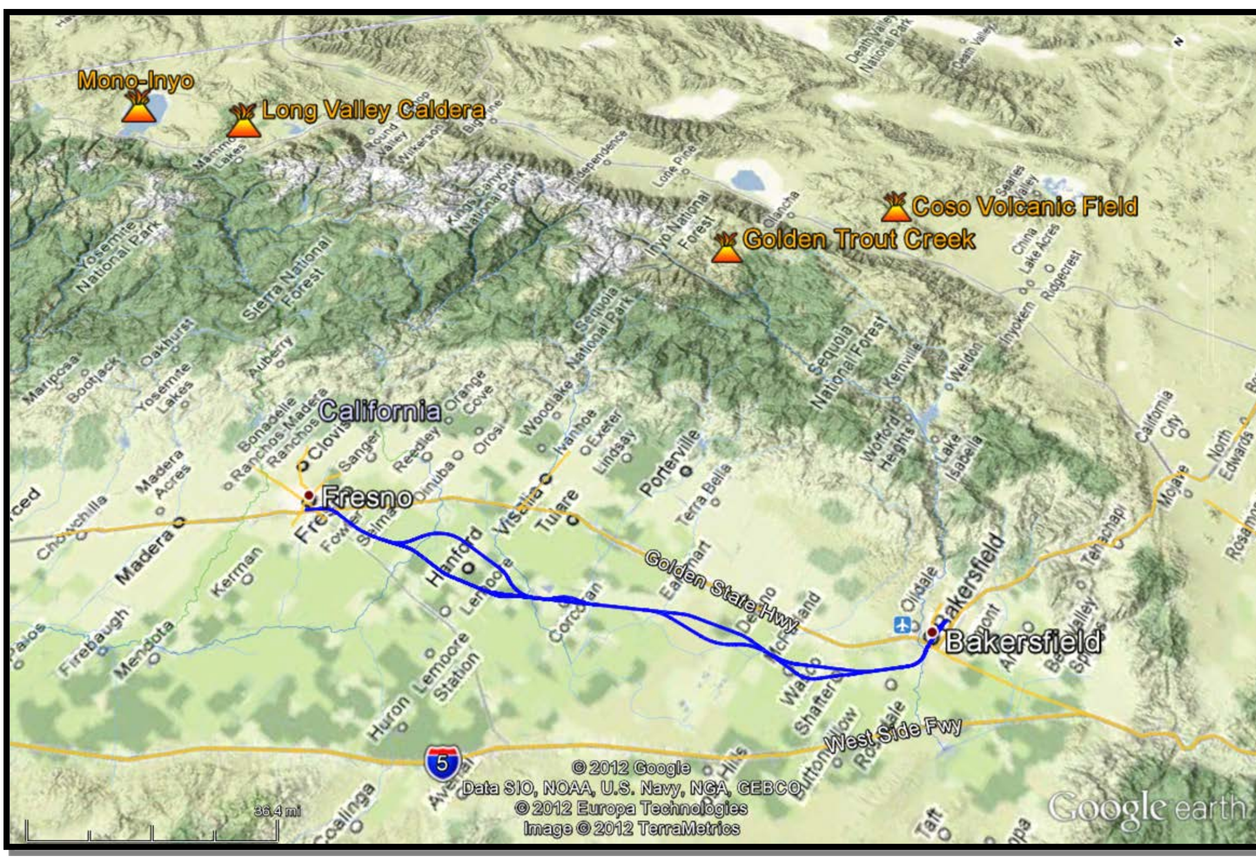

Figure 5.1-1
Volcanoes and Volcanic Fields near HST

Historically, the reported magnitude of eruptions depended very much on both the experience and vantage point of the observer. To meet the need for a meaningful magnitude measure that can be easily applied to eruptions, Newhall and Self (1982) integrated quantitative data with the

subjective descriptions of observers, resulting in the Volcanic Explosivity Index (VEI). It is a simple 0-to-8 index of increasing explosivity, with each successive integer representing about an order of magnitude increase in the volume of expulsion material.

Long Valley Caldera / Mono-Inyo Volcanic Field

The Long Valley Caldera is a seismic and volcanically active area in the eastern Sierra Nevada that lies roughly between Mono Lake and Crowley Lake about 80 miles northeast of Fresno and about 160 miles directly north of Bakersfield.

The caldera formed about 760,000 years ago following the massive (VEI 7) eruption of the Bishop Tuff, which released about 144 cubic miles of material from vents just inside the margin of the caldera (Tizzani 2009). In comparison, the 1980 Mount St. Helens eruption was categorized as either a 0.29 miles^3, VEI 5 event or a 0.06 miles^3 -VEI 4 event, depending on the reviewer.

According to the USGS (USGS g) the eruption at the Long Valley Caldera produced more than 6 cubic miles of tephra dispersed widely as ash fall with as much as 700km^3 of magma erupted as pyroclastic flows covering an area around 2,200km^2.

Figure 5.1-2 shows the spatial distribution of these materials (also known as the Bishop Ash Beds), which extend into the alignment area. Post-caldera volcanism in the Long Valley volcanic field includes activity as recent as 250 years ago and lava domes only 650 years old. Although these events are not thought to have affected the alignment itself they only serve to demonstrate that the field is still active and could affect the alignment in future years and within the lifetime of the project.

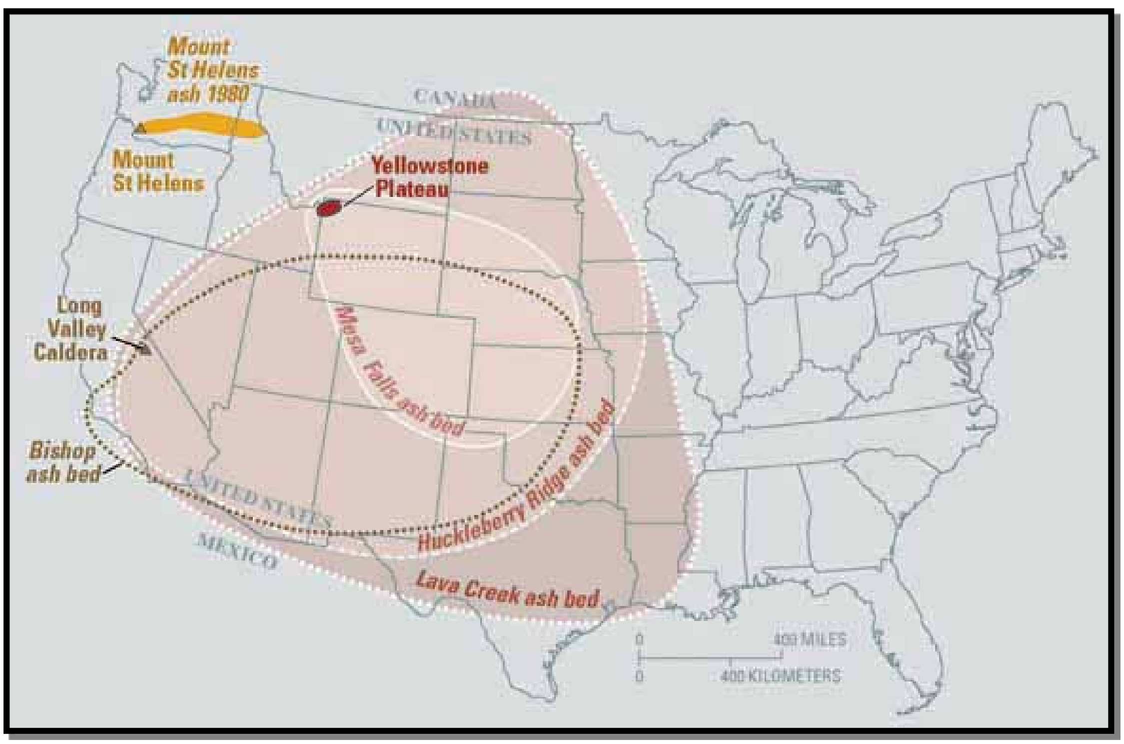

Figure 5.1-2
Distribution of Bishop Ash Beds (USGS)

04/02/2014 - RFP No.: HSR13-57

At least three volcanic ash layers, all apparently originating from the Long Valley Caldera region, occur within the oil-producing horizons of the Kern River Formation in the Kern River Field. The youngest layer is a partially devitrified vitric ash tuff composed of 37% glass, 61% smectite, 1% quartz, and 1% chlorite. Electron microprobe analysis suggests that it is equivalent to the Friant Pumice member of the Bishop Ash Bed group (0.74 Ma). Stratigraphic relationships suggest that the older ash layers may be correlative to the Glass Mountain-D (0.8-0.9 Ma) and Glass Mountain-G (0.97-1.2 Ma) ash beds (McGuire and Cullip 1989).

According to Tizzani et al. (2009), the caldera has been in a state of low activity since the spring of 1998. The cause of unrest is still debated, and hypotheses range from hybrid sources (e.g., magma with a high percentage of volatiles) to hydrothermal fluid intrusion.

Figure 5.1-3 presents evidence of surface deformation (uplift) in the caldera of up to 8.5 inches between 1996 and 1999 based on differential InSAR, leveling, GPS, two-color electronic distance meter, and microgravity data. The joint application of InSAR and microgravity data has allowed researchers to unambiguously determine that magma is the cause of unrest within the caldera (Tizzani et al. 2009).

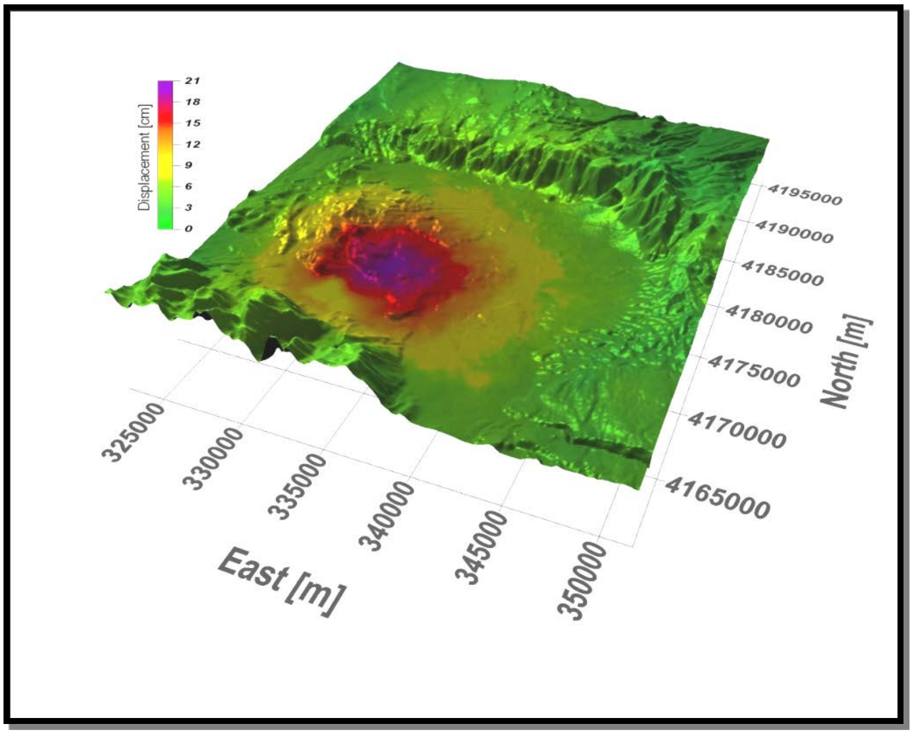

Figure 5.1-3
InSAR Image of Long Valley Caldera 1996–1999 (Pletzer et al. 2009)

USGS (USGS a) provides detailed information regarding the geological history of the Long Valley Caldera. Future eruptions are most likely to consist of one or more of the types of volcanic activity that have occurred in the past few thousand years along the Mono-Inyo Craters volcanic chain, which cuts through the western part of the caldera.

USGS (USGS a) predicts that the probability of an eruption occurring in any given year is somewhat less than 1% per year or roughly one chance in a few hundred in any given year, based on the past frequency of eruptions.

04/02/2014 - RFP No.: HSR13-57

This risk is comparable to the annual chance of a magnitude 8.0 earthquake (like the Great 1906 San Francisco Earthquake) along the San Andreas Fault in coastal California or an eruption from one of the more active Cascade Range volcanoes in the Pacific Northwest, such as Mount Rainier in Washington or Mount Shasta in California (USGS a).

Review of published ash dispersion maps for the Long Valley Caldera suggest that ash accumulation after a worst-case scenario volcanic event could be up to an inch thick along the FB Section for a VEI 4 to VEI 5 event at the Long Valley Caldera.

The event that produced the Bishop Tuff was on the order of VEI 7 and produced more than 600 times the volume of ejected material and fallout thickness than the predicted future event would produce. However, based on historical wind speeds and directions, most ash from an eruption is predicted to be deposited east of Long Valley (Figure 5.1-4) (Fresno County MHMP 2008). Since flows, lahars, or debris are not likely to reach the HST alignment, the potential hazard from volcanic activity is considered to be low.

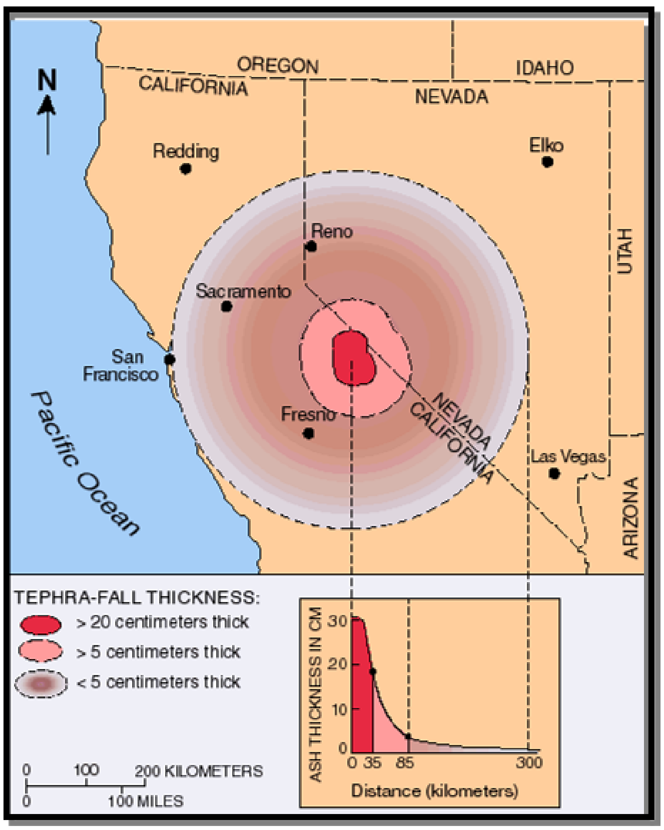

Figure 5.1-4
Long Valley Caldera Predicted Ash Fall (USGS

Golden Trout Creek

The Golden Trout Creek Volcanic Field is approximately 75 miles east of the alignment on a high plateau west of the main crest of the Sierra Nevada. The US Forest Service (USGS b) describes the nearby Monache and Templeton Mountains as small Tertiary andesitic cones with small Pleistocene basalt flows along Golden Trout Creek and at the South Fork of the Kern River with two Holocene cinder cones associated with them. The location of the Golden Trout Volcanic field relative to the HST alignment is shown on Figure 5.1-1 and Figure A20 of Appendix A.

5.2 Ground Subsidence

Ground subsidence is the gradual settlement or rapid sinking of the ground surface as a result of aquifer-system compaction, drainage of organic soils, underground mining, hydrocompaction, natural compaction, sinkholes, and thawing of permafrost (NRC 1991). The largest cause of ground subsidence for this section of the HST is attributable to the compaction of unconsolidated aquifers through excessive groundwater pumping to sustain agriculture (USGS Fact Sheet-165-00 2000b) and hydrocarbon extraction around the Bakersfield area. Subsidence from any cause accelerates maintenance problems on the CHSTP as well as existing roads, lined and unlined canals, and underground utilities. All new installations in areas suspected of subsidence should be engineered to accommodate such subsidence. The usual remedial action is that of raising the water table by injecting water or by reducing groundwater pumpage. This increases the fluid pressure in the aquifer, and in most instances, subsidence decreases or stops after a period of time. Other possible mitigation methods for subsidence-related damage are included in Chapter 9.

As outlined in the USGS Circular 1182, there are four types of ground subsidence occurring within the study area:

- **Tectonic subsidence** – A long-term, very slow sinking of the valley, which is significant only over a geologic time period.
- **Subsidence caused by the extraction of oil and gas** – This type of subsidence is currently too small to be of serious concern along the HST alignment but has proven to be locally significant in the SJV where abstraction is concentrated. Where the HST crosses oil and gas fields directly it could be significant. The USGS and California Division of Oil, Gas, and Geothermal Resources (DOGGR) monitors subsidence in oil and gas fields, and regulates oil and gas withdrawal and depressurizing of the fields.
- **Subsidence caused by withdrawal of groundwater** – This type of subsidence occurs when extraction is in quantities much larger than replacement can occur and causes a decline of the water level. It is of major concern and should be regulated and reduced, especially in urbanizing areas. Groundwater withdrawal has lowered the ground level over a large area south of Bakersfield and in other areas along the alignment.
- **Subsidence caused by hydrocompaction of moisture** – This type of subsidence is concentrated in alluvial deposits along the southwestern margins of the SJV in alluvial soils that have been subject to rapid deposition such as debris flows. Hydrocompaction is discussed separately below under Section 5.5.1 on unstable soils, because it is typically a localized hazard associated with unstable soils rather than regional. Instances of large areal hydrocompaction have been documented on the western margins of the southern SJV, although not specifically in the study area.

Some areas within the SJV have subsided as much as 30 feet (9 meters) since the 1920s. Evidence of land subsidence includes ground cracks or fissures and damage to roadways, aqueducts, and structures (Harden 2004). Figure 5.2-1 shows approximate subsidence in feet in the SJV taken from a regional perspective prior to 1975. Isolated pockets of subsidence not identified in the regional study are discussed in the next sections.

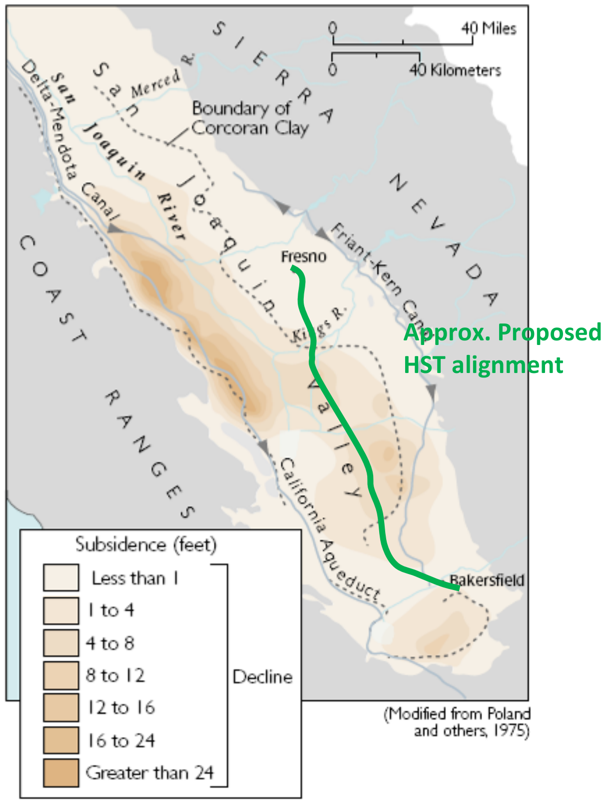

Figure 5.2-1
Total Subsidence in the SJV 1929-1975 (Galloway and Riley 1999)

Although subsidence is not a significant hazard to farmland and the general built environment, there is a risk of damage to local infrastructure. Damage directly associated with subsidence within the SJV have included decreased storage capacity in aquifers, partial or complete submergence of canals and associated bridges and pipeline crossings, collapse of well casings, and disruption of collector drains and irrigation ditches (Golloway et al. USGS Circular 1182).Consequently, HST facilities and alignments should be designed in consideration of these ongoing regional ground subsidence conditions.

Although reported settlements in the region of 30 feet are reported to have occurred in the SJV, the settlement has occurred over a large area and therefore the differential settlements along the proposed alignment are expected to be within the limits described in the TMs. However, the impact of the CHSTP on localized groundwater regimes will require careful consideration. Drainage and discharged waters will require suitable management in order to minimize the effects of erosion, piping, softening and hydrocompaction, which could result in localized settlement. Continued or new resource extraction in close proximity to the alignment could lead to differential settlements exceeding structural or railway tolerances; however, the effects of the settlement can often be mitigated by routine maintenance or designing for resiliency.

5.2.1 Oil and Gas Extraction

There are about 31,000 oil-producing wells in Kern County, which provide 66% of all the oil produced in California and about 10% of the total oil production in the United States. The aggregate annual production of Kern County oil fields is on the order of 200 to 250 million equivalent barrels. This level of extraction is not without consequence, and many areas in Kern County are experiencing accelerating rates of land subsidence. Figure A28 of Appendix A shows

the locations of oil and gas fields along the alignment. While the alignment traverses several oil and gas fields in Kern County, there are no fields within Tulare County that would appreciably affect the alignment with regard to this type of ground subsidence.

NASA and the USGS (USGS Fact Sheet 069-03 2003) monitored subsidence in the Bakersfield area over a two-year period between August 1997 and September of 1999 using satellite InSAR images. InSAR images can be combined using interferometric analysis to measure surface deformation remotely from space. This technology not only is useful in assessing aerial land subsidence but also reveals that subsidence patterns tend to be governed by the presence of faults that may not otherwise be detectible. The InSAR study of the Bakersfield area shows that within 12 miles to the north and northwest of Bakersfield, up 3.5 inches of subsidence was recorded over a two-year period (1.75 inches/year).

Oil Field Subsidence Bowl

Figure 5.2-2 shows the 1997–1999 InSAR image of the Bakersfield area as a Google Earth overlay. The image suggests that the Oil Field Subsidence Bowl is subsiding at a rate of about 1.75 inches per year (4.5 cm/year). However, since this bowl is sufficiently removed from the alignment, it does not appear that it will influence the performance of the HST.

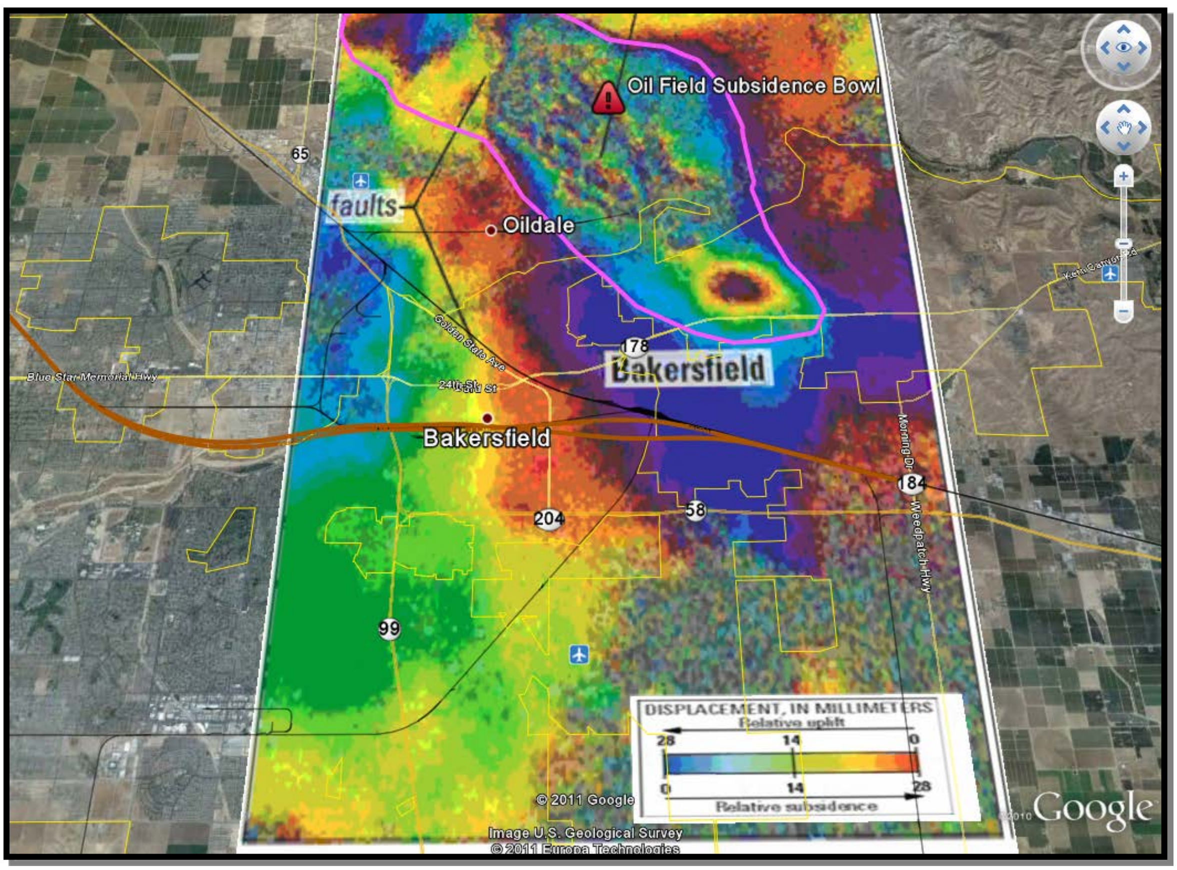

Figure 5.2-2
InSAR Imaging of Ground Subsidence near Bakersfield, CA (USGS 2003)

Using the same technology, Fielding et al. (1998) reported more rapid subsidence over the Lost Hills and Belridge oil fields. The land subsidence in those oil fields during the late 1990s was on the order of 16 inches/year. However, these fields are more than 40 miles to the west and northwest of Bakersfield.

In July of 2009, Occidental Petroleum announced discovery of a new oil and natural gas reserve of 150 to 250 equivalent million gross barrels of oil (KGNET 2009). This is approximately equivalent to the total annual production of Kern County. Occidental's find has been touted as the largest discovery in the last 35 years. The exact location of the reserve has not been disclosed but could further affect land subsidence along the HST corridor within the study area if determined to be sufficiently close. It is possible that this discovery occurred east of Shafter along the WS2 alignment where Occidental has initiated fracking operations. No data are available at this time.

5.2.2 Groundwater Extraction

Various USGS published reports and local hazard mitigation plans have been reviewed to evaluate the land subsidence that exists near the FB Section. Both the MBGP and the KMHP depict the historical subsidence bowls attributed to groundwater extraction that have been identified by various researchers and agencies over the past 50 years. Review of available regional sources indicates that subsidence in the SJV is an ongoing concern.

Some areas within the SJV have experienced as much as 30 feet of groundwater-extraction-induced subsidence since the 1920s (Harden 2004). The primary cause of subsidence within the SJV is the compaction of fine-grained sediments in the vast aquifer system underlying the Valley, following long-term groundwater extraction in excess of recharge (Planert 1996).

Since the mid-1990s, although annual surface-water deliveries generally have exceeded groundwater pumpage, water is still being removed from storage in most years in the Tulare Basin (USGS PP1766 2006). In general, groundwater pumping has slowed since its peak in the 1970s and as a result subsidence has also slowed, but not completely ceased. The majority of this subsistence is unrecoverable.

Research conducted by NASA and University of California Irvine into the state of global aquifers using satellite technologies reports that California's Sacramento and San Joaquin combined drainage basins have shed more than 24 million acre-feet (72 cubic miles) of water since late 2003. The bulk of the loss has occurred in the state's agricultural Central Valley, which depends on irrigation from both groundwater wells and diverted surface water (UC Irvine News website 2012).There are three zones of recognized subsidence related to groundwater extraction within the SJV, two of which potentially impact the proposed HST within the study area: the Arvin-Maricopa (Area C on Figure 5.2-3) and the Tulare-Wasco (Area B on Figure 5.2-3) subsidence bowls. As shown on Figure 5.2-3 in the major subsiding areas, land subsidence has continued except for a slight leveling off in the mid-1970s (Galloway and Riley 1999).

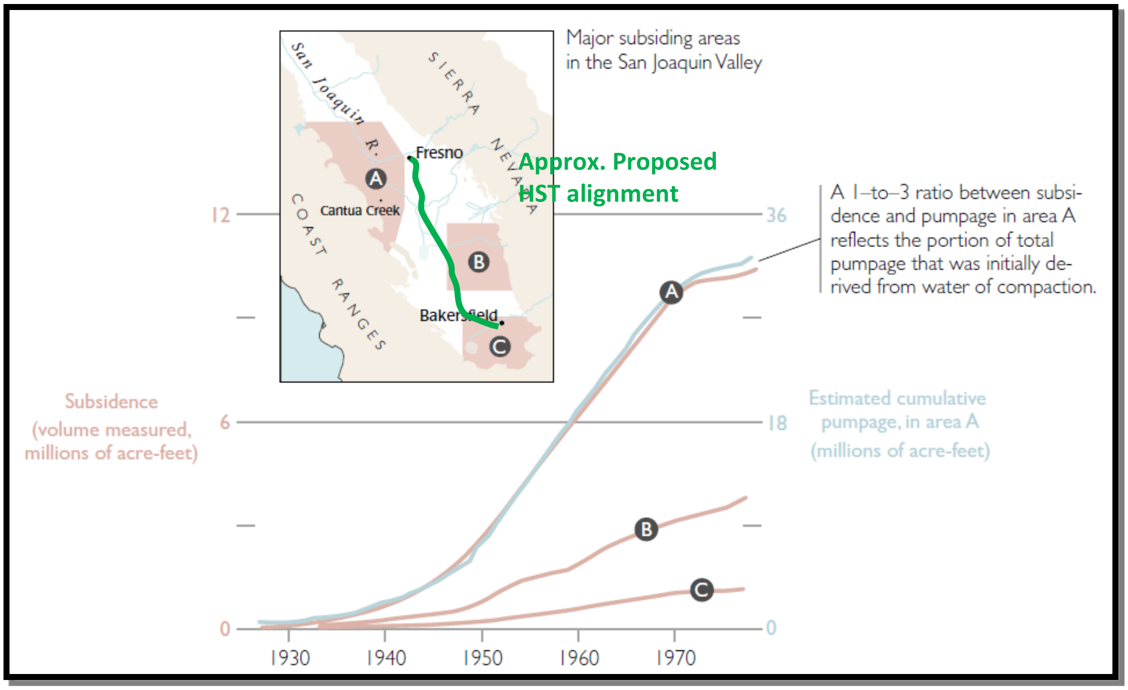

Figure 5.2-3
Historical Subsidence Zones and Rates in San Joaquin Basin (USGS 2003)

Arvin-Maricopa Subsidence Bowl

According to the MBGP, the southern part of the Bakersfield Planning Area (Area C in Figure 5.2-3) has been undergoing gradual land subsidence, with up to 4 feet of subsidence over a 40-year period prior to about 1965. This subsidence area is generally known as the Arvin-Maricopa Subsidence Bowl. The Kern County General Plan (Chapter 4 – Safety Element) suggests that areas south of Bakersfield in this bowl subsided as much as 4 feet between 1926 and 1965 with up to an additional 3 feet of subsidence between 1965 and 1970. Other sources place the total subsidence south of Bakersfield closer to 9.5 feet prior to 1972. Since there are relatively few oil fields in this region, it is inferred that the source of the subsidence bowl south of Bakersfield is predominantly due to groundwater extraction (USGS 1986 and 1989). Sources depicting subsidence contours of the Arvin-Maricopa Subsidence Bowl suggest its influence extends as far north as Highway 58 (see Figure 5.2-4). The colored fringes on Figure 5.2-4 represent 1-foot subsidence contours that developed between 1929 and 1973.

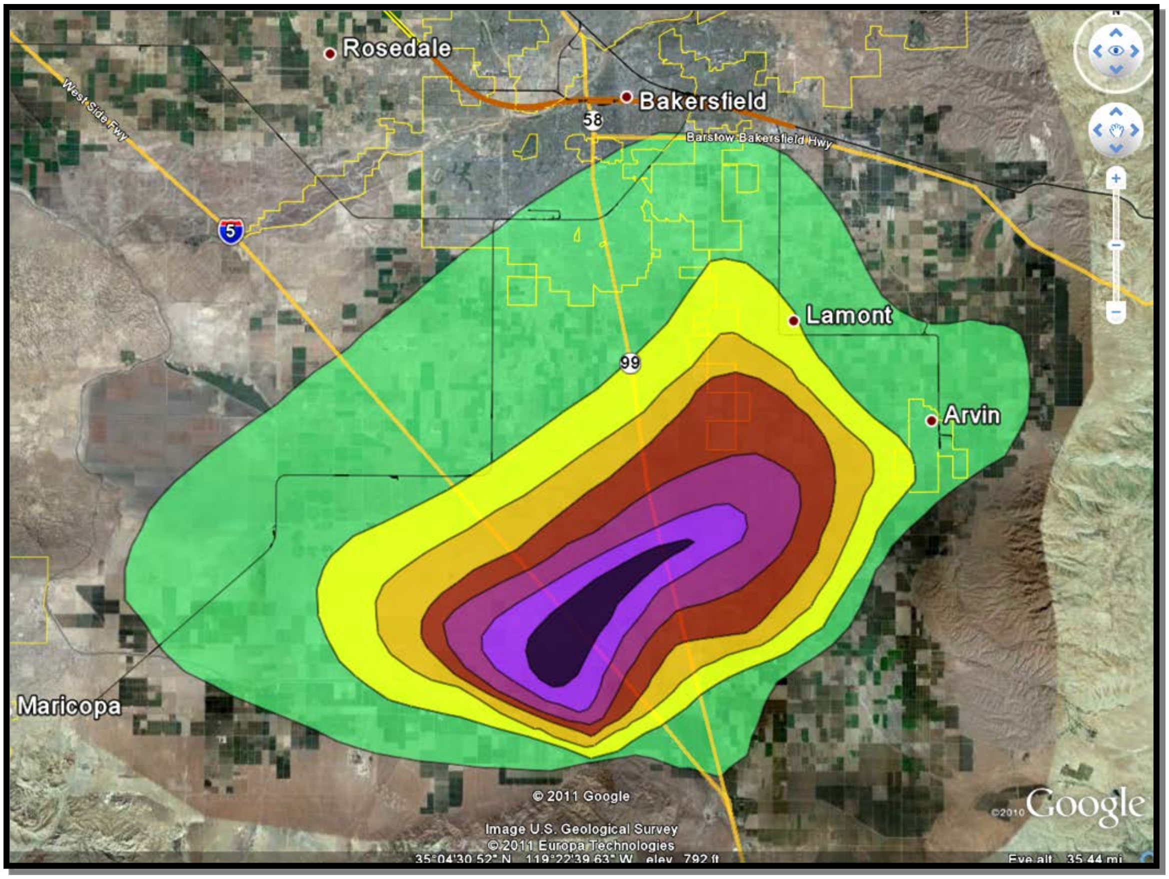

Figure 5.2-4
Limits of Arvin-Maricopa Subsidence Bowl (Kern County General Plan 2007)

Tulare-Wasco Subsidence Bowl

The KMHP and USGS subsidence maps both show that another area along the alignment is experiencing significant groundwater-extraction-induced land subsidence between Wasco and Tulare. This subsidence area is generally known as the Tulare-Wasco Subsidence Bowl and is shown on Figure 5.2-5. The outermost contour (red-orange/rust) on Figure 5.2-5 represents two feet of subsidence; contours are at 2-foot increments. The maximum subsidence in this bowl was determined to be 12 feet at the time of the studies (1970) with the loci of maxima following Highway 99 between Pixley and Delano. Nearly all of Subsection FB-G of the study area is located within the historical 4- to 6-foot subsidence contours of the bowl. The northern 2.5 miles of Subsection FB-H are within the historical 2- to 4-foot subsidence contour.

A recent abstract (Brant et al. 2005) suggests that InSAR imaging from 1992 to 1995 is available. However, we were not able to locate these images during this study. The text of the abstract describes ongoing subsidence occurring during the time data was collected as follows:

> InSAR detects a 15- x 15-km feature just south of Pixley subsiding at a rate of about 0.8 inches/year between 1992 and 1995. Two overlapping satellite tracks of interferograms for this area identify a small 1.5-km-wide subsidence feature located in the southwest part of the larger-scale subsidence bowl. The maximum subsidence rate of this small-scale localized feature is approximately 35 mm/year.

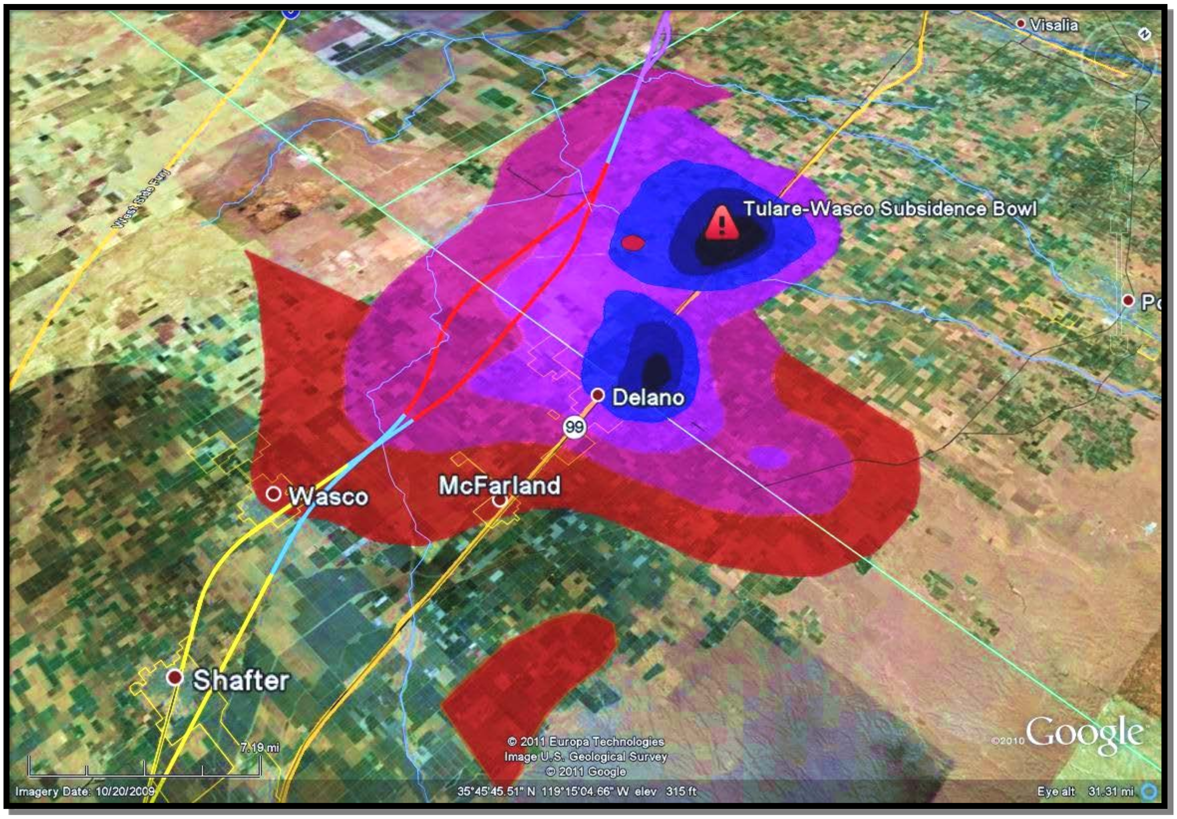

Figure 5.2-5
Tulare-Wasco Subsidence Bowl (Poland et al. 1975)

The northern (royal-blue) 8-foot subsidence bowl shown on Figure 5.2-5, centered south of Pixley, is approximately the same size and is assumed to be at the same location as the "2 cm/year" subsidence area described in the abstract. This bowl encroaches within 1.5 miles of the HST alignment. The "1.4 inches/year" subsidence zone is approximately located in Figure 5.2-5 (in bright red) within the 8-foot subsidence bowl. Until the actual InSAR images from the Pixley study can be obtained, no specific comments can be made regarding the anticipated subsidence of the HST alignment within the Tulare-Wasco Subsidence Bowl over the design life.

Subsidence in the Tulare-Wasco bowl may not be strictly attributable to groundwater extraction alone and may be partially influenced by the structural geology associated with tectonic activity noted in the Corcoran Clay in Section 3.2.8. The Corcoran Clay was secondarily folded during deposition of the overburden valley fill (Prokopovich 1976b). Synclinal features in the clay have historically manifested themselves as increased surface subsidence in zones of piezometric decreases.

According to Prokopovich (1976b) along the present San Luis Canal, a more or less uniform historic piezometric decline of 635 feet has resulted in 3 to over 23 feet of subsidence. Maximum subsidence has occurred in areas underlain by small, buried synclines in the Corcoran Clay, and minimum subsidence has occurred over anticlines. The deepest portions of the Tulare-Wasco bowl appears to have formed over such a synclinal/graben feature (see Figure 5.2-6).

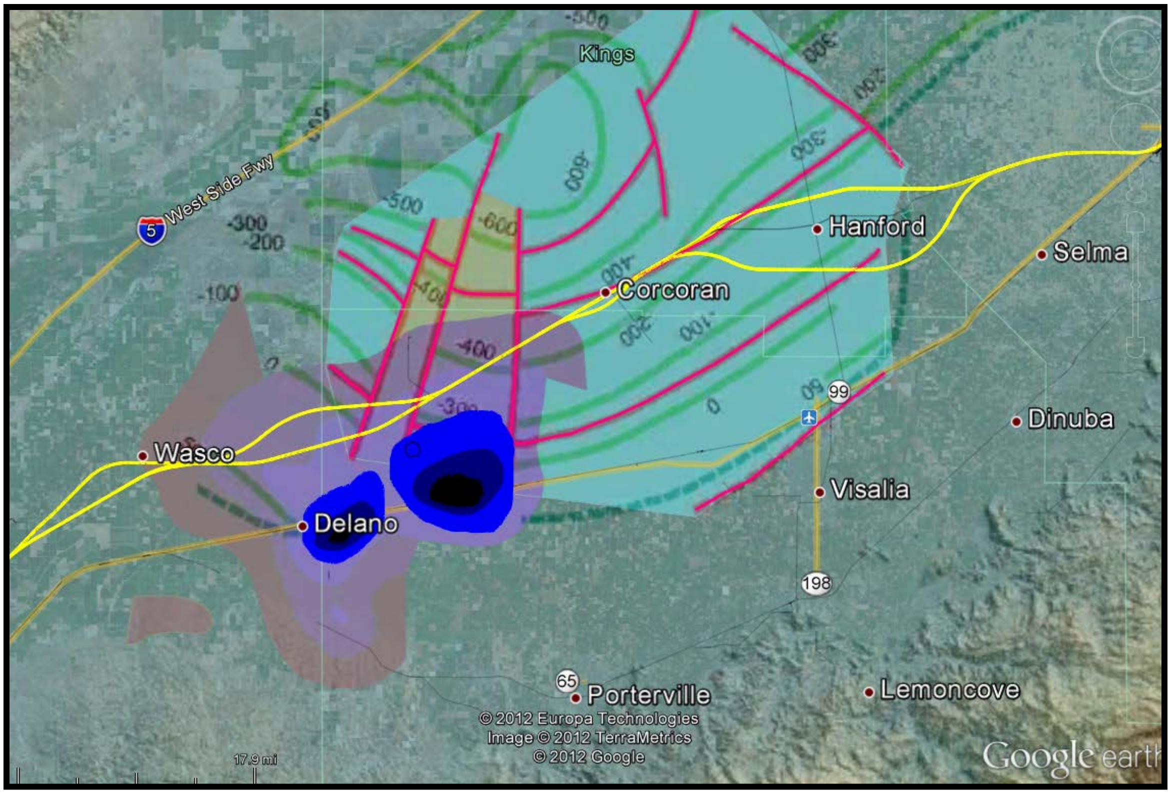

Figure 5.2-6
Corcoran Clay Influence on Tulare-Wasco Subsidence Bowl
(after Saleeby and Foster 2003 and Poland 1975)

Figure 5.2-6 shows contours of the top of the Corcoran Clay (green lines) as well as known, unmapped/inferred faults (red lines) interpreted by Saleeby and Foster (2003). Based on the review of seismic reflection data, Saleeby and Foster interpret that the Tulare Lake basin began forming by 2.2 mya and combined with borehole log and core data produced an isopach map to determine its total thickness. Saleeby and Foster describe the findings of the research:

> At 0.615 mya the Tulare Lake basin formed a semicircular embayment protruding eastwards about 25 miles from the regional NNW-trending depositional trough pattern that typifies the rest of the Great Valley. A topographic closure to the sub-basin of more than 300 feet relative to the rest of the Great Valley trough demonstrates the uniqueness of the basin and its greatly accelerated relative tectonic subsidence rate. The published structure contour and isopach maps also show sharp changes in slope values and sharp bends in their trends suggesting the presence of unmapped faults.

The northern subsidence bowl, centered just about 2 miles south of the Town of Pixley, appears to align with a fault-bounded, 200-foot, down-throw expressed in the top of the clay. Similarly, the southern bowl appears to align with an adjacent fault-bounded feature in the top-of-clay contours. Both subsidence bowls show evidence of broader, more pronounced contouring toward the western sides, i.e., toward the low point in the top of the Corcoran Clay at -600 feet MSL. In fact, the shape of the contours seems to be elongated in the down-slope direction of the clay surface, toward the low point in the top of the clay. Figure 5.2-6 suggests that the profile of the Tulare-Wasco Bowl is being influenced by the structural features of the Corcoran Clay.

Hanford Subsidence Bowl

Regional Subsidence in the vicinity of Hanford was documented by Poland (1975) and is shown on Figure 5.2-7. Between 1929 and 1975 a subsidence bowl had developed south of Hanford that measured more than 8 feet in depth. At Highway 198, where the HST crosses the alignment, the subsidence depth measured by Poland was on the order of 6.5 feet. Global positioning surveys conducted in along Hwy 198 in 2004 showed a subsidence trough centered at Armona with a depth of about 9.2 feet (Ikehara et al. 2010).

By comparison of Google Earth ground surface elevations to elevations shown on the HST alignment drawings as shown on Figure 5.2-8, subsidence is on now the order 15 feet on Hwy 198. If true, this would suggest that subsidence rates have accelerated from about 1.2 inches per year between 1975 and 2004 to about 12 inches per year between 2004 and 2010 (assuming the HST elevations were measured in 2010). This rate increase may be reflective of the 60’ drop in the groundwater table in the past decade. More recent evaluations of subsidence in the Hanford-Corcoran area are discussed in Section 5.2.4

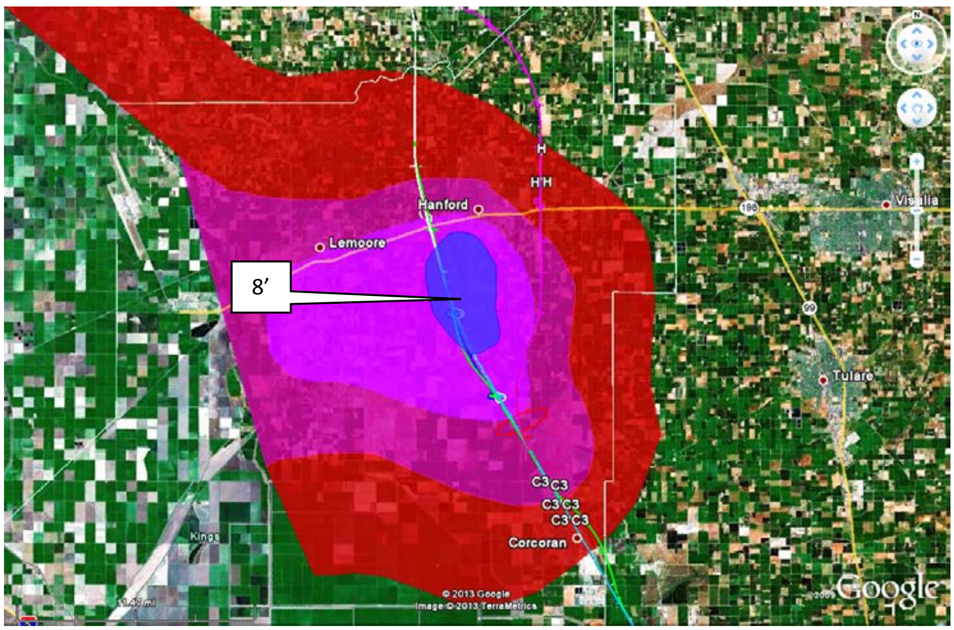

Figure 5.2-7
Hanford Subsidence Bowl (after Poland et al. 1975)

5.2.3 Other Subsidence Sources

Hydrocompaction is a near-surface process where high porosity materials above the historical water table that have strong montmorillonite clay interparticulate bonds are wetted (for example, recently by irrigation for agricultural purposes) causing these clay bonds to drastically weaken and collapse/crush under the load of the overlying sediments.

In contrast to the broad, slowly progressive, and generally smooth subsidence due to deep-seated aquifer-system compaction, the irregular, localized, and often rapid differential subsidence due to hydrocompaction is readily discernible and produces an undulating surface of hollows and hummocks with local relief, typically of 3 to 5 feet (Galloway and Riley 1999). Hydrocompaction is discussed separately below under the section on collapsible soils since it is typically a localized hazard associated with unstable soils rather than aerial or regional.

Subsidence also occurs when highly organic soils are drained during land use conversion for agricultural or commercial purposes. Soils of this type, frequently termed peat or muck, are formed in marshes, bogs and other poorly drained settings with water tables near the surface. Land subsidence can also be attributed to simple peat oxidation over time. Regionally, subsidence due to peat oxidation appears to be confined to the delta east of San Francisco. USGS maps do not indicate that there is any risk associated with this type of subsidence within the study area.

5.2.4 Current Alignment Subsidence

The RC made a preliminary evaluation of subsidence along the alignment by comparing the current (2011) ground surface elevation along the alignment taken from the FB 15% Record Set Plan & Profile Sheets to ground surface elevations based on Google Earth.

Online sources suggests Google Earth elevations are adjusted to fit elevations on the historic USGS quads based on the NAVD88 datum however, Google Earth elevations are consistently 3 feet higher than USGS quads (available from online sources as Google Earth overlays). The datum for those quads is NAD27, while Google Earth is based on the WGS84 datum. Since the Google Earth elevations matched FB 15% survey elevations at Bakersfield and Fresno (where no measureable historic subsidence has occurred), it was determined that the Google Earth elevations would serve as a baseline to determine current subsidence levels.

Figure 5.2-8 illustrates that at Hwy 198 Google Earth indicates the ground surface elevation is EL. 243. The programmatic (recently surveyed in 2010-11) ground surface elevation is at about 228. Thus, about 15 feet of subsidence has occurred at Hwy 198 since 1929.

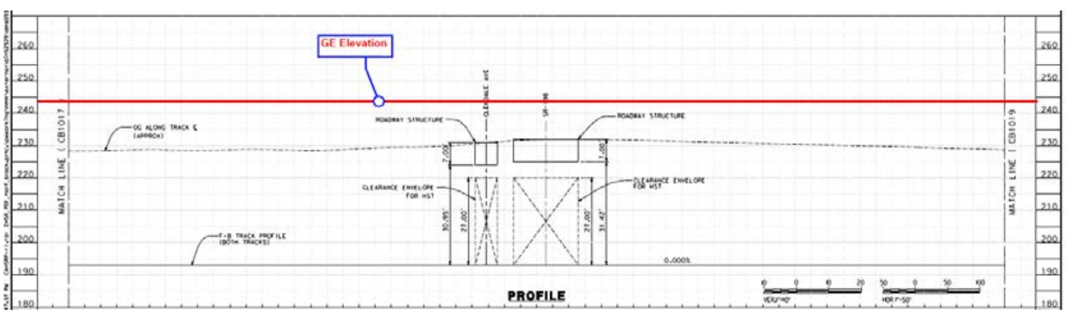

Figure 5.2-8
Current Subsidence Determination

In the southern segments of the alignment through Bakersfield, this review indicates there is very little subsidence. Near the Town of Pond the apparent subsidence is about 6 feet while at the Kern/Tulare county line subsidence increases to 10 feet. Prior to 1975, Poland et al. only recorded about 6 feet of subsidence at the county line.

At Allensworth, where a pre-1975 subsidence of 8 feet had been recorded by Poland (see Figure 5.2-5), the comparison suggests total subsidence is now on the order of 17 feet increasing to nearly 20 feet just south of the Lakeland Canal. Apart from the area west of Hanford discussed below, this area has the highest recorded distortion along the alignment at about 1/1100. North of Corcoran, at Nevada Avenue, the apparent subsidence is about 15 feet reducing to about 8 feet at Jersey Avenue where the alignment crosses Highway 43.

Apparent subsidence in the Hanford area at Idaho Avenue may be as much as 17 feet on the HW Bypass alignment. At Highway 198 subsidence is currently estimated about 9 to 13 feet for the east and west bypass options, respectively. Three to four miles to the north, the subsidence at Flint Avenues reduces to 3 feet along the alignment east of Hanford while the HW Bypass

appears to have subsided about 13 feet. At Excelsior Avenue the apparent subsidence along the HW Bypass option is about 3 feet. Thus, the distortion between Flint Avenue and Excelsior Avenue is about 1/1050.

At the Kings River, the Google Earth grades along both the east and west Hanford bypass alignments meet the 15% Record Set grade elevations, so there is no apparent subsidence. There does not appear to be any subsidence north of the Kings River on any of the alignments.

The foregoing evaluation of distortions along the alignment is by no means comprehensive and intended only to bracket areas of potential concern and provide a preliminary quantitative assessment of the magnitude of potential distortions. Existing topography at this stage of the design is based on satellite imagery. Once more refined topography is available the foregoing assessment should be revisited.

Jet Propulsion Laboratory Subsidence Rate Study

Late in 2012, the RC reached out to the USGS for additional data on subsidence in the Central Valley. Representatives of the USGS referred to a study conducted by NASA's Jet Propulsion Laboratory (JPL), where InSAR data were collected between 2007 and 2011. The data collection was terminated when the satellite conducting the measurements reached the end of its lifespan. Data compilation and conclusory publication is in progress as of spring 2013. Publication of the data is expected in late 2013. The InSAR used Japan's ALOS-PALSAR L-band satellite radar, which has a 25-centimeter wavelength (Tom Farr; geologist; JPL; Pasadena, California; March 12, 2013; personal communication).

Data recorded over the four-year study indicated a maximum linear subsidence rate of approximately 22.5 centimeters (8.85 inches) per year centered northwest of Allensworth on the HST alignment. The subsidence bowl appears to stretch about 35 miles trending northwest–southeast between Hanford and Allensworth directly parallel to the C1/C3 and P alignments.

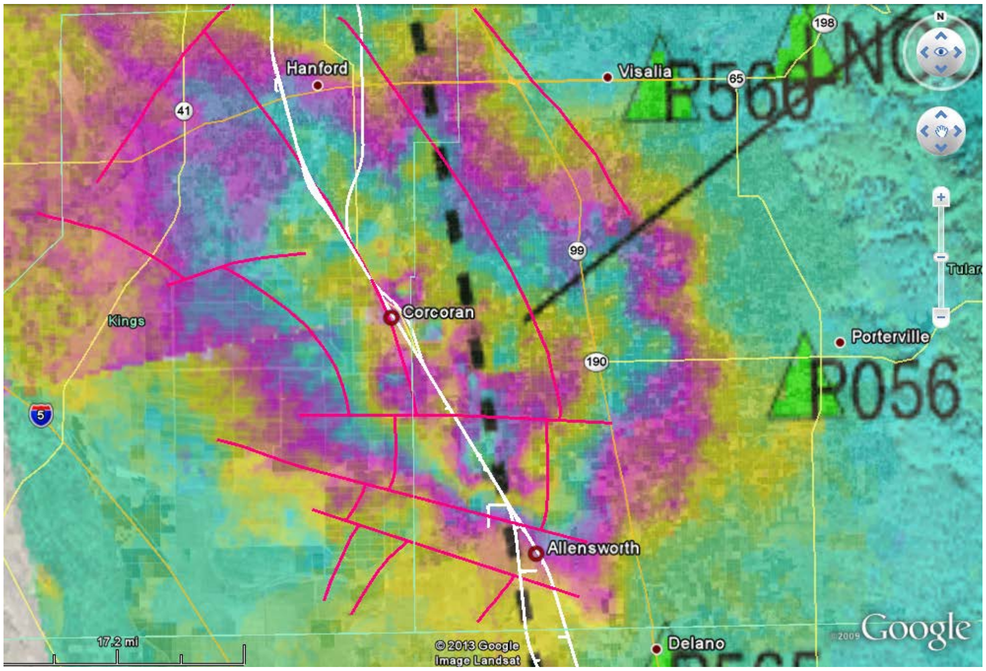

Figure 5.2-9
JPL Subsidence Evaluation

Figure 5.2-9 shows the limits of subsidence bowl measured by JPL. Though USGS does not consider the Corcoran (E) clay to be a significant contributor (Farr 2013), the subsidence zone appears to coincide with the location of the Corcoran Clay faults discussed above. The JPL data and conclusions have not yet been completely reviewed; however, the rate of settlement of one cycle of the color fringe has been established at 11.25 cm/year. Figure 5.2-8 shows the location of the maximum rate of subsidence, i.e., two cycles of the color fringe.

While the JPL subsidence rate evaluation indicates a subsidence rate of about 11 cm/year where the alignment crosses the HWY 198, survey data at this intersection (as discussed above) and spot checks conducted elsewhere along this reach of the alignment again by the RC in 2013 indicate the subsidence rates could be as high as 30.5 cm/year. The likely presence of a major subsidence bowl directly beneath the alignment emphasizes the need to build resilience into the permanent design of the high-speed rail trackway.

5.3 Areas of Difficult Excavation

Difficulties may be encountered during excavation in a variety of ways. Hard material, such as bedrock (unlikely to be encountered) or cemented material such as hardpan, provide the greatest difficulty. Sources of information used to make the following assessment were the USDA Soil Surveys for Eastern Fresno Area County; Kings County; Tulare County, Western Part; and Kern County, Northwestern Part that generally consider the top 5 feet of soils only (F-B CHSTP SGGR 2010). The sections below describe localized issues, organized by segment.

Table 5.3-1 summarizes the locations where hardpan is likely to be encountered and is discussed in more detail below. It should be noted that the possibility of encountering hard pan during the lifetime of the project, over the full depth of the piles if highly likely and the following sections have been prepared in order to understand the general characteristics of the materials that are likely to be present and encountered at depth.

Table 5.3-1
Areas of Difficult Excavation (USDA)

Subsection	Station	Reason for Difficulty	Depth (in)
Fresno	W Clinton Ave to W Church Ave	Hardpan	12–48 (4–17 in. thick)
Rural North	E Davis St to E Barrett Ave	Hardpan	20–40 (0–3 in. thick)
Rural South	County Road J22 to County Line	Hardpan	20–36 (4–12 in. thick)

5.3.1 Subsection FB–A Fresno

For more than half of HST Subsection FB–A Fresno, areas of difficult excavation should not be encountered. However, the San Joaquin soil series, which makes up approximately 30% of Subsection FB–A between W Clinton Avenue and W Lorena Avenue, has a hardpan present between 12 to 48 inches below the surface (USDA and NRCS 2008a). The hardpan can vary from 4 to 17 inches thick. Other soil series that have a similar hardpan are the Greenfield (W Belmont Avenue to Tuolumne Street) and Madera series (W Lorena Avenue to W Church Avenue), which make up 8% and 4% of the Fresno section, respectively (USDA and NRCS 2008a).

Figure A21a of Appendix A shows the distribution of soils likely to have hardpan associated with them relative to the proposed alignments.

This hardpan may impede the excavation of surface material prior to the beginning of construction and is also likely to be present at depth and could be a constraint to pile construction. To mitigate this issue, special equipment will be necessary to advance the works. Future subsurface investigations will determine these characteristics, such as the extent and strength of the hardpan.

5.3.2 Subsection FB–B Rural North

For the majority of HST Subsection FB–B Rural North, areas of difficult excavation should not be encountered. However, the El Peco soil series, which is found between E Davis Street to E Barrett Avenue, has a hardpan present between 20 to 40 inches below the surface (USDA and NRCS 2008a). The hardpan can vary from 0 to 3 inches thick.

Figure A21b of Appendix A shows the distribution of soils likely to have hardpan associated with them relative to the proposed alignments. There is a possibility of encountering hard-pan at depth which could be a constraint to pile construction. As in Subsection FB–A, this hardpan may impede the excavation of surface material. Future subsurface investigations will determine the extent and strength of the layer.

5.3.3 Subsections FB–C Kings River Crossing through FB–F Tule River Crossing

Areas of difficult surface excavation should not be encountered within these subsections (USDA and NRCS 2009a). However, subsurface investigations should be conducted to verify this assumption. There is a possibility of encountering hard-pan at depth which could be a constraint to pile construction.

5.3.4 Subsections FB–G Rural South

Only one soil unit (Gareck-Atesh-Kimberlina) within the FB-G Rural South segment indicates the presence of a weakly cemented hardpan within the upper 5 feet from County Road J22 to Kern/Tulare county line and is shown on Figure A21c of Appendix A. There is a possibility of encountering hard-pan at depth which could be a constraint to pile construction.

5.3.5 Subsections FB–H Wasco to Shafter through FB–L Bakersfield South

As shown on Figures A21d and A21e, areas of difficult excavation should not be encountered within these subsections (USDA and NRCS 2009a). However, subsurface investigations should be conducted to verify this assumption. There is a possibility of encountering hard-pan at depth which could be a constraint to pile construction.

The presence of loose soils may cause difficulties during temporary excavations through sidewall collapse. If shallow groundwater is present then groundwater ingress into excavations may occur which is likely to require temporary de-watering. The combination of shallow groundwater and loose soils

5.4 Expansive Soils

Expansive soils are those that undergo a significant increase in volume during wetting, and shrink in volume as they decrease in water content. Expansive soils can cause significant damage to structures due to increases in uplift pressures. Soils are generally classified as having low, moderate, and high expansive, or shrink-swell, potential. The percentage of clay particles present in the soil often determines the potential for the soil's expansive behavior. Soils high in clay content usually have high expansive potentials, and more granular sands and gravels generally have low expansion potential (F-B CHSTP SGGR 2010). Sources of information were the USDA Soil Surveys for Eastern Fresno Area County; Kings County; Tulare County, Western Part; and Kern County, Northwestern Part. It should be noted that the comments relating to expansive soils are based on data from the top 5 feet of soil only. No reference here is made to soils deeper than 5 feet that may be expansive.

To mitigate the effects of highly expansive soils, structures should be designed taking the shrink-swell potential of the soil into account. While the sections below show generally the areas of the HST that may be subject to expansive soils, a more detailed subsurface investigation should be conducted. This investigation should include laboratory testing, and specifically Atterberg limits, to determine the exact expansive potential of the soil. The presence and severity of expansive soils along the alignment in the study area are shown on Table 5.4-1.

The distribution of moderate to highly expansive soils along the proposed alignment within the study area is shown on Figure A22a to A22e of Appendix A.

Table 5.4-1
Extent of Expansive Soils (USDA)

Segment	Station	Expansive Potential	Depth (in)
Fresno	W Clinton Ave to W Lorena Ave	Low – Moderate	0-16
Fresno	W Clinton Ave to W Lorena Ave	Moderate	16-30
Fresno	W Lorena Ave to E Church Ave	High	20-33
Rural North	E Barrett Ave to E Harlan Ave	Moderate	0–42
Kings River Crossing	Highway 43 to Cole Slough	Moderate	0–42
Hanford Station	SR 198 to Hanford Armona Rd	Moderate	9–22
Rural Central	Hanford Armona Ave to Kansas Ave	Low–Moderate	Varies
Rural Central	Kansas Ave to Avenue 144	Low–High	Varies
Tule River Crossing	Avenue 144 to Avenue 128	Moderate	Varies
Rural South (Tulare)	Avenue 128 to Avenue 36	High	Varies
Rural South (Tulare)	Avenue 36 to County Line	Low	Varies
Rural South (Kern)	County Line to Phillips Road	Low–Moderate	Varies
Wasco and Shafter	Phillips Road to Hwy 58	Low–Moderate	Varies
Bakersfield North	Hwy 58 to Coffee Road	Low	Varies
Kern River Crossing	Coffee Road to Oak Street	Low	Varies
Bakersfield South	Oak Street to Oswell Street	Low	Varies
Bakersfield South	Oswell Street to Comanche Drive	Low–Moderate	Varies

While the sections below show generally that some areas of the HST may be subject to expansive soils, a more detailed subsurface investigation should be conducted. This investigation should include laboratory testing, and specifically Atterberg limits, to determine the exact expansive potential of the soil.

To mitigate the effects of highly expansive soils, structures should be designed taking the shrink-swell potential of the soil into account. The USDA Soil Surveys definition of expansion potential is more onerous than the engineering definition, as such due to the lack of information and to err on the side of caution we have adhered to the USDA Soil Surveys definitions until further GI is carried out.

5.4.1 Subsection FB–A Fresno

The soils along HST Subsection FB–A Fresno consists mainly of silty sand, silt, or lean clay and therefore have a low expansive potential. The San Joaquin soil series, however, has a low to moderate expansive potential (USDA Soil Survey definition) to 16 inches and a moderate expansive potential (USDA Soil Survey 2008a) from 16 to 30 inches below the surface (Huntington 1971). The plasticity of these soils ranges from non-plastic to 30. The San Joaquin soil series makes up approximately 30% of the Fresno section and is generally found between W Clinton Avenue and W Lorena Avenue. The Madera soil series, which makes up 4% of the section and is found between W Lorena Avenue to E Church Avenue, has a low expansive potential to 20

inches and a high expansive potential from 20 to 33 inches below the surface (USDA Soil Survey 2008a). The plasticity index of the soil between 20 and 33 inches is 20 to 35.

Figure A22a of Appendix A shows the distribution of expansive soils relative to the HST alignment for Fresno.

5.4.2 Subsection FB–B Rural North

The soils along HST Subsection FB–B Rural North consist mainly of sand, silty sand, silt, or lean clay and therefore has a low expansive potential (USDA Soil Survey 2008a, Huntington 1971). The Pachappa soil series, however, has a moderate expansive potential (USDA Soil Survey 2008a) to 42 inches below ground surface. The plasticity index of these soils is non-plastic to 15. The Pachappa series is found from E Barrett Avenue to E Harlan Avenue. Only the H alignment traverses this series in the vicinity of Highway 43.

Figures A22a and A22b of Appendix A show the distribution of expansive soils relative to the proposed HST alignment for the Rural North subsection.

5.4.3 Subsection FB–C Kings River Crossing

The soils along HST Subsection FB–C Kings River Crossing are mainly silt and silty sand and therefore have a low expansive potential (USDA Soil Survey 2009a). However, between Highway 43 and the Cole Slough, the H alignment traverses the Pachappa soil series which has a moderate expansive potential (USDA Soil Survey 2009a) to 42 inches below ground surface. The plasticity index of these soils is non-plastic to 15. Figure A22b of Appendix A shows the distribution of expansive soils relative to the proposed alignment for the Kings River subsection.

5.4.4 Subsection FB–D Hanford Station

The northern portion of HST Subsection FB–D Hanford Station, from Fargo Avenue to SR 198, is mainly silty sand with a low expansive potential. From SR 198 to Hanford Armona Road on the H Alignment, the soil is mainly lean clay with a low expansive potential (USDA Soil Survey 2009a) near the surface but a moderate expansive potential (USDA Soil Survey 2009a) between 9 and 22 inches below the surface (Arroues 1986). These soils have a plasticity index of 10 to 20.

Figure A22b of Appendix A shows the distribution of expansive soils relative to the proposed HST alignment for Hanford Station.

5.4.5 Subsection FB–E Rural Central

Along HST Subsection FB–E Rural Central, the majority of the soil has a low expansive potential. However, soils that are part of the Corona, Garces, and Lakeside series have a moderate expansive potential (USDA Soil Survey 2009a) (Arroues 1986). These soils have plasticity indexes between 10 and 20. Between Kansas Avenue and Avenue 144, the expansive potential (USDA Soil Survey 2009a) of the soil varies from low to high. The silty sand of the Cajon and Grangeville series have low expansive potential, while the lean clays of the Garces, Goldberg, and Lakeside series have moderate expansive potential. In a few areas, fat clays are present in the Goldberg and Lakeside series, which have high expansive potential (USDA Soil Survey 2009a) and a plasticity index between 20 and 30.

Figures A22b and A22c of Appendix A show the distribution of expansive soils relative to the proposed HST alignment for Rural Central.

5.4.6 Subsection FB–F Tule River Crossing

The soils along HST Subsection FB–F Tule River Crossing have a moderate expansive potential (USDA Soil Survey 2009b) due to the presence of lean clay and clayey sand in some areas. Figure A22c of Appendix A shows the distribution of expansive soils relative to the proposed HST alignment for Tule River Crossing.

5.4.7 Subsection FB–G Rural South

Figures A22c and A22d of Appendix A show the distribution of potentially expansive soils along the Rural South subsection relative to the proposed HST alignment. Within Tulare County the soils along HST Subsection FB–G Rural South from Avenue 128 to Avenue 36 the alignment crosses the Gepford-Houser-Armona and the Nahrub-lethent-Psochanet series. These soils are considered to have a high potential for expansion with PIs between 5 and 30. Between Avenue 36 and County Line, the Gareck-Atesh-Kimberlina series has a low potential for expansion (USDA Soil Survey 2009b).

Within Kern County between County Line and Airport Road the Garces-Panoche and Milham soils have a moderate potential for shrink-swell with PIs ranging between 5-20. From Airport Road to Peterson Road the Kimberlina-Wasco series considered to have a low potential for expansion. From Peterson Road to Poso Creek the alignment again crosses the Garces-Panoche and McFarland soil; both are characterized as moderately expansive. South of Poso Creek to about Whistler Avenue the alignment crosses the Kimberlina-Wasco series and from Whistler to Phillips Road it crosses the McFarland series (USDA Soil Survey 2009b)

5.4.8 Subsection FB–H Wasco to Shafter

The HST alignments alternatives in Subsection FB-H traverse the Milham soil series in the vicinity of 7th Standard Road which considered expansive with a low to moderate shrink-swell potential. This soil series has between 5 to 30% clay and a Plasticity Index ranging between 0 and 15. Figures A22d and A22e of Appendix A shows the distribution of potentially expansive soils in the Wasco to Shafter subsection relative to the proposed HST alignment (USDA Soil Survey 2008b).

5.4.9 Subsection FB–J Bakersfield North

The soils along HST Subsection FB–J Bakersfield North are mainly silt and silty sand and therefore have a low expansive potential (USDA Soil Survey 2008b). See Figure A22e of Appendix A.

5.4.10 Subsection FB–K Kern River Crossing

The soils along HST Subsection FB–K Kern River Crossing are mainly silt and silty sand and therefore have a low expansive potential (USDA Soil Survey 2008b). See Figure A22e of Appendix A.

5.4.11 Subsection FB–L Bakersfield South

The soils along HST Subsection FB–K Kern River Crossing are mainly silt and silty sand and therefore have a low expansive potential. However, between Oswell Street and Weedpatch Highway is the Panoche-Millham-Kimberlina series which is moderately expansive due to the presence of lean clay and clayey sand in some areas (USDA Soil Survey 2008b). Figure A22e of Appendix A shows the distribution of expansive soils relative to the proposed HST alignment for the Bakersfield South subsection.

5.5 Collapsible and Compressible Soils

5.5.1 Collapsible Soils and Hydrocompaction

Collapsible soils are soils that undergo settlement upon the addition of water and or load, which weakens or destroys soil particle bonds, reducing the bearing capacity of the soil. Other mechanisms for soil collapse include the sudden closure of voids within a soil, whereby the sudden decrease in volume results in loss of the soil's internal structure, causing the soil to collapse. Specific soil types, such as loess and other fine-grained fluvial soils, are most susceptible to collapse (CHSTP-F-B GS&S 2011).

Soils within the SJV have similar textures to those prone to hydrocompaction, with classifications ranging from poorly graded silty sand to clay (predominantly montmorillonite) (Hunt 1984). Gypsum-rich soils, laden with sulfates, are also prone to volume loss and settlement when wetted. As discussed by Muckel (2004) gypsum is somewhat soluble so it has several undesirable effects; improper surface drainage can dissolve the salts in the soil beneath foundations. Irrigation in areas with gypsiferous soils also can result in dissolution. This material goes into solution or easily erodes and forms solution cavities, pipes, and gullies.

The California Groundwater Bulletin 118 describes the gypsiferous clays and gravels in the SJV to be derived predominantly from Coast Range sources and are, thus, a likely source of some of the subsidence attributed to hydrocompaction on the southwestern margins of the valley.

Galloway et al. (1999) describes further the hazards presented by hydrocompaction in the USGS Circular 1182 (1999):

> The hazards presented by hydrocompaction are somewhat mitigated by the fact that the process goes rapidly to completion with the initial thorough wetting, and is not subject to reactivation through subsequent cycles of decreasing and increasing moisture content. However, if the volume of water that infiltrates the surface on the first wetting cycle is insufficient to wet the full thickness of susceptible deposits, then the process will propagate to greater depths on subsequent applications, resulting in renewed subsidence. Also, an increase in the surface load such as a bridge footing or a canal full of water can cause additional compaction in pre-wetted sediments.

Windblown sediments such as the dune sands have a high potential for hydrocompaction. Dune sands have been identified between Fresno and the Kings River along the alignment. Although there has been no documented cases of hydrocompaction of dune sands in this region of the SJV and, based on satellite imagery, the area has been substantially cultivated and irrigated, a risk of hydrocompaction remains and should be further investigated.

Historical SJV Hydrocompaction

According to Prokopovich (1976a) historically, the SJV has had "spotty" occurrences of reported hydrocompaction predominantly concentrated along the Coast Range foothills on the western margin of the southwestern portion of the SJV, where it has affected two major water conveyance systems — the San Luis Canal and the California Aqueduct. Zones of historical hydrocompaction in the SJV are shown on Figure 5.5-1 (Ireland et al. 1984, Williamson 1989).

Prokopovich (1976a) explains that the

> typical deposits affected by hydrocompaction, are composed of clayey Pleistocene interfan piedmont alluvium deposited mostly as mudflows. Such interfans are composed of minor, coalescent poorly defined fans of small arroyos. These isolated patches of

alluvium, susceptible to hydrocompaction, are separated by fluvial alluvium of major ephemeral Coast Range streams.

Up to 20 feet of hydrocompaction in this region has been observed in the areas shown in red on Figure 5.5-1 below. Some hydrocompaction cracks were over 6 feet wide and were probed to a depth of about 30 feet (Prokopovich 1976a).

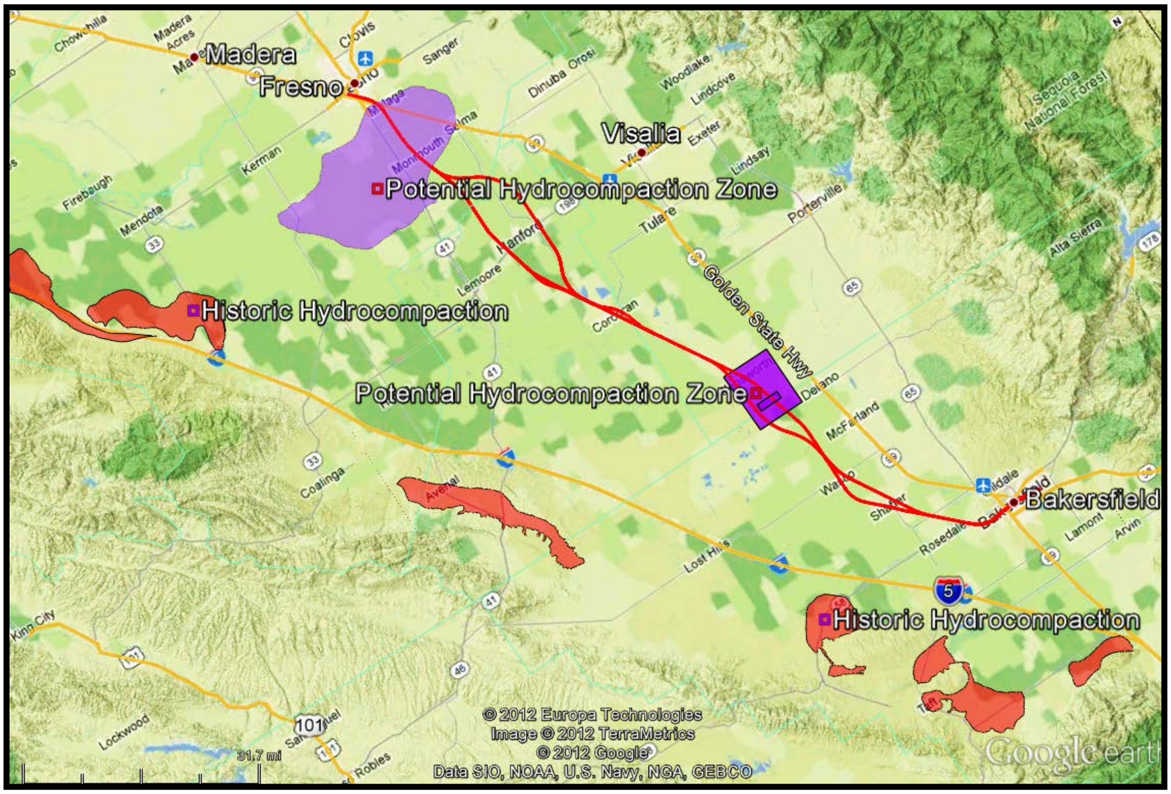

Figure 5.5-1
Historical SJV Hydrocompaction Zones (Ireland et al. 1984 and Williamson 1985)

Extensive investigation into the mechanisms and ground conditions required for hydrocompaction was completed in the 1950s prior to the Construction of the California Aqueduct. As detailed by Galloway et al in the USGS Circular 1182 (1999) the combined field and laboratory studies demonstrated that hydrocompaction in the SJV occurred only in the following:

- Alluvial-fan sediments above the highest prehistoric water table.
- Areas where sparse rainfall and ephemeral runoff had never penetrated below the zone subject to summer desiccation by evaporation and transpiration.

According Prokopovich (1976a) the initial total thickness of sediments susceptible to hydrocompaction in studies conducted in the SJV were determined to be on the order of 200 feet. With the onset of advanced farming techniques and widespread irrigation, much of the damage to infrastructure (i.e., wells, ditches, roads and bridges) caused by hydrocompaction occurred in the 1940s and 1950s. Prokopovich (1976a) explains that much of the alluvium initially susceptible to hydrocompaction has become “stable” from wetting by irrigation.

Galloway et al. (1999) describe the effects that standard flood irrigation techniques had on virgin valley soils in the 1940s and 1950s. It was found that irrigation caused settlement of fields of

typically 3 to 5 feet, causing surface hollows and a hummocky relief (see Figure 5.5-2). In those areas where prolonged ponding of water occurred, settlements of 10 feet or more occurred on susceptible soils.

Figure 5.5-2
SJV Irrigation-Induced Hydrocompaction (Galloway 1999)

HST Hydrocompaction Risk Zone

Detailed evaluations of the collapsible potential of soils along the HST alignment could not be found likely because the HST alignment is located outside areas in the SJV that have historically experienced hydrocompaction (Figure 5.5-1). Moreover, outside of the urban corridors, the alignment traverses through heavily irrigated farmlands. Any hydrocompaction through irrigated farmlands has likely long since been exhausted. However, two potential areas of risk are identified on Figure 5.5-1.

Windblown sediments such as the dune sands have a high potential for hydrocompaction. Dune sands have been identified within Subsection FB-B: Rural North between Fresno and the Kings River. Although there has been no documented cases of hydrocompaction in this region of the SJV and, based on satellite imagery, the area has been substantially cultivated and irrigated, a risk of hydrocompaction remains and should be further investigated.

Within Subsection FB-G: Rural South between the Deer Creek Viaduct and the Garces Highway a more focused evaluation of hydrocompaction risk may be necessary since it appears (from satellite imagery) that these plots are relatively undisturbed. However, although this zone has not historically been subjected to heavy irrigation, the northern half of the zone was likely periodically subject to inundation from Tulare Lake. The limits of the historical Tulare Lake bed (Sholes 2006) and the zone identified as an HST risk for hydrocompaction are shown on Figure 5.5-3.

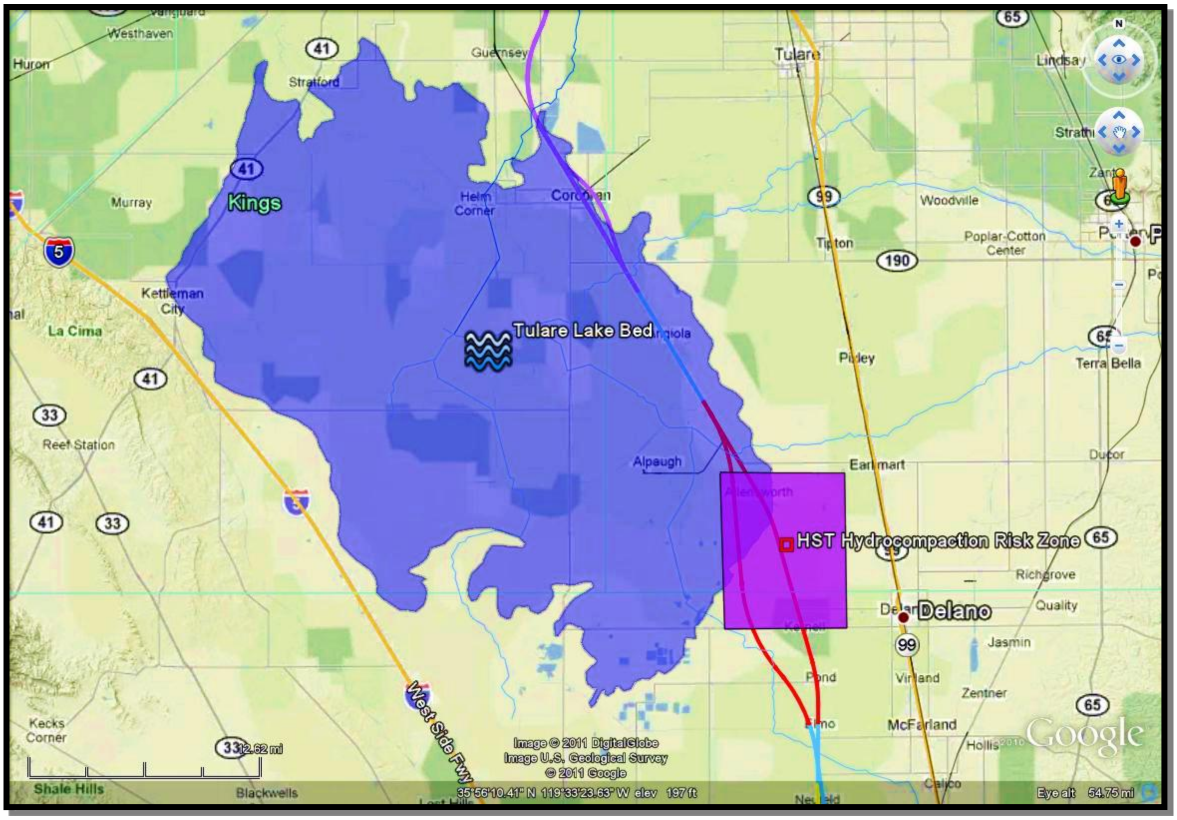

Figure 5.5-3
HST Hydrocompaction Risk Zone

Some data from consolidation testing within the Bakersfield subsection of the alignment was available for this study and indicates that the surficial soils have a collapse potential of between 0.5 to 1.5% upon wetting under the 1500 psf load increment. In addition, historical borehole data in the vicinity of Fresno suggest a collapse potential of between 0.5 and 3% upon wetting Therefore, laboratory testing will be required to further characterize and identify soils susceptible to collapse within the proposed HST corridor (F-B CHSTP SGGR 2010).

Currently, the proposed drainage methods include collecting water from the right-of-way footprint and directing the collected water to soakaways parallel to the alignment. This method may lead to collection of surface water build-up and potential hydrocompaction. To evaluate the presence of collapsible soils, further investigation is needed during the 30% GI.

5.5.2 Compressible Soils

Soft organic soils are potentially highly compressible and are likely to be encountered beneath the footprint of the proposed alignment. These soils present significant engineering hazards that can affect the long term performance of rail line and associated infrastructure. Settlement associated with compressible soils has the potential to severely compromise the operational serviceability of the HST.

Soft organic soils are often associated with low-energy dispositional environments such as flood plains, lakes, or marshes. A review of the published literature indicates that soft compressible soils are likely to be associated with the footprint of Lake Tulare around Corcoran and the Tulare Marsh deposits. The proximity of historical lakes and marshes to the proposed alignment is shown on Figure A5 of Appendix A.

The Rural South (FB-G) and Wasco Shafter (FB-H) subsections of the alignment were historically marshy and boggy areas that were subject to seasonal inundation. Although these areas are now drained it is likely that soft organic soils prone to settlement and low bearing capacity are likely to be encountered. The presence of soft organic soils may also increase the risk from the 'bow wave' effect.

Alignment-specific GIs will need to be performed to investigate the presence and extent of these deposits beneath the footprint of the proposed alignment.

5.6 Soil Corrosivity

Soil corrosivity involves the measure of the potential of corrosion for buried steel and concrete caused by contact with some types of soil. Knowledge of potential soil corrosivity is often critical for the effective design parameters associated with cathodic protection of buried steel and concrete project elements. Factors including soil composition, soil chemistry, moisture content, and pH affect the response of steel and concrete to soil corrosion. Soils with high moisture content, high electrical conductivity, high acidity, and high dissolved salts content are most corrosive. In general, sandy soils have high resistivities and are the least corrosive. Clay soils, including those that contain salt water, can be highly corrosive (F-B CHSTP SGGR 2010).

The risk of corrosion is expressed as "low," "moderate," or "high." For uncoated steel, this is based on soil drainage class, total acidity, electrical resistivity near field capacity, and electrical conductivity of the saturation extract. For concrete, this is based on soil texture, acidity, and amount of sulfates in the saturation extract (USDA and NRCS 2008a). Sources of information were the USDA Soil Surveys for Tulare County, Western Part; and Kern County, Northwestern Part.

The risk of encountering soils corrosive to concrete and steel is shown in Table 5.6-1 below and is based on general values given to entire soil series' encountered along the alignment as shown on Figures A7a and A7e. Soils along the alignment are predominantly classified as moderately to highly corrosive to uncoated steel as shown on Figures A23a to A23e. These figures show the distribution of soils corrosive to uncoated steel in the northern reaches of the alignment. South of the Tule River Crossing, all soils are classified as highly corrosive to uncoated steel; thus, there was no need to prepare figure differentiating the risk in this section of the study area.

Mitigation measures include providing additional structural thickness to account for potential corrosion losses, cathodic protection such as galvanized coatings, and other non-galvanized coatings such as fusion-bonded epoxy or polymeric barrier coating for buried steel.

The distribution of moderate to highly corrosive soils along the proposed alignment within the study area is shown on Figure A24a through A24e of Appendix A.

Mitigation measures include the use of Type IV or Type V cement in concrete mix designs. Corrosivity testing should also be conducted during the GI phase of the project to determine site-specific values and more refined recommendations regarding mitigation strategies.

Table 5.6-1
Risk of Corrosion for Uncoated Steel and Concrete (USDA)

Segment Name	Station	Risk of Corrosion Uncoated Steel	Risk of Corrosion Concrete
Fresno	W Clinton Avenue to E Central Avenue	Moderate–High	Low–Moderate
Rural North	E Central Avenue to E Davis Street	Moderate-High	Low
Rural North	E Davis Street to E Harlan Avenue	High	Low
Kings River Crossing	E Harlan Avenue to Fargo Avenue	High	High
Hanford Station — H	Fargo Avenue to Hanford Armona Road	High	Moderate–High
Hanford Station — HW & HW2	Fargo Avenue to Hanford Armona Road	High	High
Rural Central	Hanford Armona Road to Kansas Avenue	High	High
Rural Central	Kansas Avenue to Avenue 144	Low–High	Moderate–High
Tule River Crossing	Avenue 144 to Avenue 128	High	Moderate
Rural South (Tulare)	Avenue 128 to County Line	High	High
Rural South (Kern)	County Line to Airport Road	High	Moderate
Wasco and Shafter	Phillips Road to Hageman Road	High	Low
Bakersfield North	Hageman Road to Coffee Road	High	Low
Kern River Crossing	Coffee Road to Oak Street	High	Low
Bakersfield South	Oak Street to Comanche Drive	High	Low–Moderate

5.6.1 Subsection FB–A Fresno

The soils along HST Subsection FB–A Fresno have a moderate to high risk of corrosion for uncoated steel and a low to moderate risk of corrosion of concrete (USDA and NRCS 2008a). The San Joaquin soil series, which makes up approximately 30% of the Fresno section and is generally found between W Clinton Avenue and W Lorena Avenue, has a high risk of corrosion for uncoated steel and a moderate risk of corrosion for concrete. This San Joaquin soil is generally comprised of a combination of silty sand, silty clay and lean clay and has a soil pH ranging from 5.6 to 6.5 near the surface and 6.1 to 7.3 to a depth of 5 feet with zero soil salinity (USDA and NRCS 2008a).

The Hanford soil series, which makes up approximately 24% of the Fresno section and is generally found between W Franklin Avenue and Kern Street and between W North Avenue and W Muscat Avenue, has a moderate risk of corrosion for uncoated steel and a low risk of corrosion for concrete. The Hanford soil series is composed of a combination of silty sand and silt, has a soil pH from 6.1 to 7.3, and zero soil salinity (USDA and NRCS 2008a).

The Hesperia soil series, which makes up approximately 27% of the Fresno section and is generally found between E Church Avenue and E Central Avenue, has a high risk of corrosion for uncoated steel and a moderate risk of corrosion for concrete. The Hesperia soil series is generally composed of a combination of silty sand, silt, and lean clay, has a soil pH from 6.1 to 7.8 near the surface and from 7.4 to 8.4 to a depth of 5 feet with zero soil salinity. However, in approximately 10% of these areas, the soil pH is as high as 7.9 to 9.0 and the salinity is from 4.0 to 8.0 mmhos/cm (USDA and NRCS 2008a).

Figures A23a and A24a show the potential of the soils in Fresno to be corrosive to uncoated steel or concrete, respectively, relative to the proposed HST alignment.

5.6.2 Subsection FB–B Rural North

The soils along HST Subsection FB–B Rural North have moderate to high risk of corrosion for uncoated steel and low risk of corrosion of concrete (USDA and NRCS 2008a). The Delhi and Hanford soil series, which are part of the Hanford-Delhi-Hesperia Association and are found between E Central Avenue and E Davis Street, have moderate risk of corrosion for uncoated steel and low risk of corrosion for concrete (USDA and NRCS 2008a). The Hanford-Delhi-Hesperia Association has a soil pH from 6.1 to 7.3 and zero soil salinity. The Hesperia and Dello soil series, which are also part of the Hanford-Delhi-Hesperia Association and are found between E Central Avenue and E Davis Street, have high risk of corrosion for uncoated steel and low risk of corrosion for concrete.

The Hesperia and Dello soil series have soil pH levels from 6.1 to 8.4 that increase with depth, and salinity values of 0.0 to 2.0 mmhos/cm. The soil series between E Davis Street and E Harlan Avenue (El Peco and Pachappa) generally have a high risk of corrosion for uncoated steel and a low risk of corrosion of concrete. The El Peco and Pachappa soil series have pH levels from 7.8 to 9.6 and salinity values from 4.0 to 16.0 mmhos/cm (USDA and NRCS 2008a).

Figures A23a and A23b and Figures A24a and A24b show the potential of the soils in Rural North to be corrosive to uncoated steel and to concrete, respectively, relative to the proposed HST alignment.

5.6.3 Subsection FB–C Kings River Crossing

The soils along HST Subsection FB–C Kings River Crossing have high risk of corrosion for uncoated steel and high risk of corrosion of concrete (USDA and NRCS 2009a) south of Cole Slough and Kings River. Over 85% of the soils along the alignments in this segment, including those in the Kimberlina and some of the Nord series, have a high risk of corrosion for uncoated steel and a low risk of corrosion for concrete. The Kimberlina and some of the Nord soil series have pH levels of 6.6 to 8.4 and salinity values of 0.0 mmhos/cm to 0.4 mmhos/cm. A portion of the soils in the Nord series, however, has a high risk of corrosion for concrete; these soils are located intermittently between Denver Avenue and Dover Avenue and have pH levels of 8.5 to 9.0 and salinity values of 4.0 to 8.0 mmhos/cm (USDA and NRCS 2009a).

Figures A23b and A24b of Appendix A show the potential of the soils in Kings River Crossing subsection to pose a hazard to uncoated steel or concrete, respectively, relative to the proposed HST alignment.

5.6.4 Subsection FB–D Hanford Station

The northern portion of HST Subsection FB–D Hanford Station H alignment , from Fargo Avenue to SR 198, is underlain by Kimberlina soils and has a high risk of corrosion for uncoated steel and a high risk of corrosion for concrete (USDA and NRCS 2009a). These soils have pH levels of 7.9 to 8.4 and salinity values of 4.0-8.0 mmhos/cm. Along the southern portion of the H alignment of

the Hanford Station segment SR 198 to Hanford Armona Road, the El Peco series, has a high risk of corrosion for uncoated steel and a moderate risk of corrosion for concrete. The El Peco soil series has pH levels of 6.6 to 9.6 and salinity values of 2.0 to 16.0 mmhos/cm (USDA and NRCS 2009).

HST Subsection FB–D Hanford Station HW alignment traverses the Nord series which has a high risk of corrosion for concrete and uncoated steel. These soils are located intermittently between Denver Avenue and Dover Avenue and have pH levels of 8.5 to 9.0 and salinity values of 4.0 to 8.0 mmhos/cm.

Figures A23b and A24b of Appendix A show the potential of the soils in Hanford Station subsection to pose a hazard to uncoated steel or concrete, respectively, relative to the proposed HST alignment.

5.6.5 Subsection FB–E Rural Central

For the soils along HST Subsection FB–E Rural Central, between Hanford Armona Road and Kansas Avenue, the majority of the soils (Kimberlina and Nord soils) have high risk of corrosion for uncoated steel (USDA and NRCS 2009a) and a high risk of corrosion to concrete with similar properties as those described above for Subsection FB-D.

Between Kansas Avenue and Avenue 144, the majority of the soils have high risk of corrosion for uncoated steel. Only the Pachappa series has low risk of corrosion for uncoated steel. For concrete, the preponderance of the soils in this reach have a high risk of corrosion with exception of the El Peco and Gambogy series' which have a moderate risk of corrosion to concrete. The pH of all soils ranges from 6.6 to 9.6 and the salinity varies from 0.0-16.0 mmhos/cm (USDA and NRCS 2009a).

Figures A23b, A23c, A24b, and A24c of Appendix A show the potential of the soils in the Rural Central subsection to pose a hazard to unprotected steel and concrete, respectively, relative to the proposed HST alignment.

5.6.6 Subsection FB–F Tule River Crossing

The Gambogy soils along HST Subsection FB–F Tule River Crossing have a high risk of corrosion for uncoated steel and a moderate risk of corrosion for concrete (USDA and NRCS 2009b). The soils have a pH ranging from 7.4 to 8.4 and a salinity of 0.0-4.0 mmhos/cm.

Figures A23c and A24c of Appendix A show the potential of the soils in Tule River Crossing subsection to pose a hazard to uncoated steel or concrete, respectively, relative to the proposed HST alignment.

5.6.7 Subsection FB–G Rural South

Figures A24c and A24d of Appendix A show the distribution of soils potentially corrosive to concrete in the Rural South subsection relative to the proposed HST alignment. Within Tulare County the soils along HST Subsection FB–G Rural South from Avenue 128 to within 0.5 miles south of Avenue 128, the Gambogy-Biggriz soils are moderately corrosive to concrete with salinities of 0.0 to 8.0 mmhos/cm., The remainder of the soils in Tulare County are highly corrosive to concrete with salinities of 0.0 to 30.0 mmhos/cm and highly corrosive to uncoated steel with pH levels from 7.4 to 9.6 (USDA and NRCS 2009b).

In Kern County between County Line and Airport Road, the Garces-Panoche soils also have high potential for corroding uncoated steel with pH levels from 7.4 to 9.0. A moderate potential for corrosion to concrete exists in this series with salinity ranging from 0.0 to 8.0 mmhos/cm. From

Airport Road to the end of Subsection G at Phillips Road are the Kimberlina-Wasco, McFarland, and Milham soil series. These soils are not particularly corrosive to concrete, with salinity values between 0.0 and 4.0 mmhos/cm, but they are highly corrosive to uncoated steel with pH levels between 6.6 and 8.4. Within this section there are possible intrusions of the Garces-Panoche series at both Spangler Road and Sherwood Avenue (USDA and NRCS 2009b).

All soils in Tulare County and Kern County with Subsection FB-G are highly corrosive to steel and concrete as shown on Figure A23c and A23d of Appendix A (USDA and NRCS 2008, 2009, 2009a).

5.6.8 Subsection FB–H Wasco to Shafter

The HST alignments alternatives in Subsection FB-H traverse three surficial soil types: the Kimberlina-Wasco, the Milham and the Delano-Lewkalb-Drive. As shown on Figure A24d of Appendix A, the potential for elements corrosive to concrete in this subsection is low. However, the risk of uncoated steel corrosion is high as shown on Figures A23d and A23e. These soils have a pH ranging from 6.6 to 8.4 and a salinity of 0.0-4.0 mmhos/cm (USDA and NRCS 2008b).

5.6.9 Subsection FB–J Bakersfield North

Soils in Subsection FB-J are generally not corrosive to uncoated steel as shown on Figure A23e of Appendix A. The majority of Subsection FB-J traverses the Kimberlina-Wasco series. As shown on Figure A23e of Appendix A, the potential for elements corrosive to concrete in this subsection is low. However, the risk of uncoated steel corrosion is high as with all other subsections south of the Tule River as shown on Figure A23e of Appendix A. These soils have a pH ranging from 6.6 to 8.4 and a salinity of 0.0-4.0 mmhos/cm (USDA and NRCS 2008b).

5.6.10 Subsection FB–K Kern River Crossing

The majority of Subsection FB-K traverses the Kimberlina-Wasco series. As shown on Figure A24 of Appendix A, the potential for elements corrosive to concrete is low. However, the risk of uncoated steel corrosion is high as shown on A23e. These soils have a pH ranging from 6.6 to 8.4 and a salinity of 0.0-4.0 mmhos/cm (USDA and NRCS 2008b).

5.6.11 Subsection FB–L Bakersfield South

The Bakersfield South subsection predominantly traverses the Kimberlina-Wasco series west of Washington Street and the Delano-Chanac series east of Washington Street. These soils are classified as highly corrosive to steel with low potential for sulfate attack on concrete. These soils have pH levels from 6.6 to 8.4 and salinity values of 0.0 to 4.0 mmhos/cm. The Panoche-Millham-Kimberlina series is between Oswell Street and Weedpatch Highway. These soils have pH levels from 6.6 to 8.4 and general salinity values of 0.0 to 4.0 mmhos/cm. However, within the Panoche series salinity can range between 4 and 16 mmhos/cm, which is moderately corrosive to concrete (USDA and NRCS 2008b).

All soils in Subsection FB-L are highly corrosive to uncoated steel as shown on Figure A23e of Appendix A.

5.7 Erodible Soils

Certain soil types demonstrate a higher potential for erodibility from the forces of water (rainfall and runoff) than other soil types do. This potential is expressed in the Universal Soil Loss Equation by the soil erodibility factor K. The K factor is defined as a function of texture, organic matter content, structure size class, and subsoil saturated hydraulic conductivity. As a rule of thumb, K-factors in excess of 0.4 are considered highly susceptible to erosion (F-B CHSTP SGGR

2010). Sources of information for this report were the USDA Soil Surveys for Tulare County, Western Part and Kern County, Northwestern Part.

The biggest potential source of erosion comes from the rivers that cross the alignment. A review of the CDWR shows that flow data for the Kings River is extremely variable with low flows of less than 3 cubic feet/sec for most of the year, which are not likely to cause erosion, and intermittent high flows of a maximum of 850 cubic feet/sec, which have a high potential to cause erosion (CDWR 2010) see Figure 5.7-1.

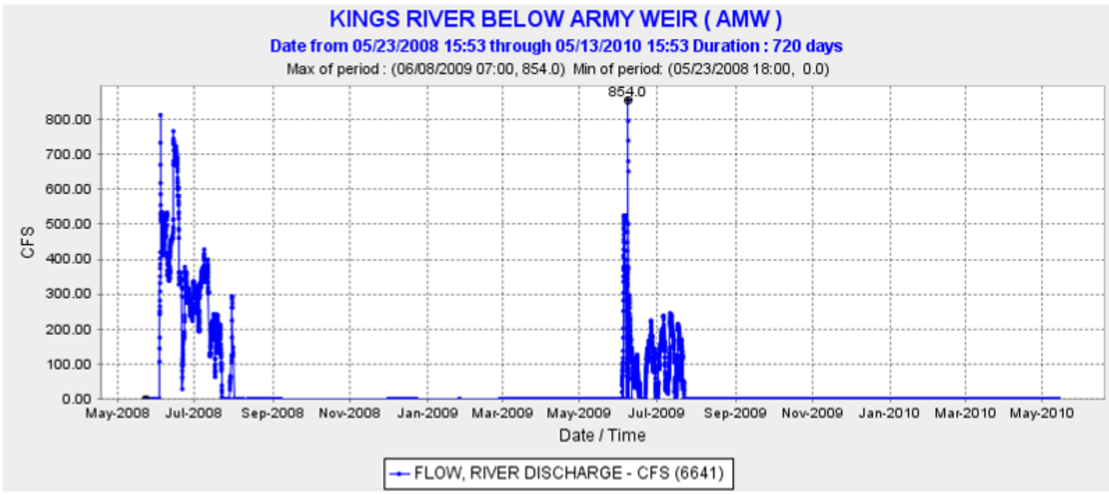

Figure 5.7-1
Flow for Kings River for May 2008 to May 2010 (CDWR)

The high flows are not during the spring snowmelt season as might be anticipated, but rather in the summer months. These summer high flows are probably due to controlled release of flow for agricultural reasons during the height of summer. Mitigation measures against channel erosion are to channelize flows near the alignment, rock armor, greater river bank structures, planting, detention basins, silt fences, brush barriers, velocity dissipation devices, sediment traps, temporary sediment basins, and other controls.

Erosion potential of soils along the alignment are shown in Table 5.7-1 below. According to the Erodible Soils Statewide (North) in the Statewide Programmatic EIR/EIS (Authority 2005), the BNSF corridor from FB, which includes all of the alternative alignments evaluated in this report, does not cross any areas of erodible soils. However, the erodibility of the soil is a significant concern during the lifetime of the project from pre-construction through construction and the operational phase of the HST.

As discussed by Muckel (2204) certain activities, particularly construction, often leave the soil disturbed, bare, and exposed to water, which can lead to increased risk of erosion. If construction must take place during the high rainfall (winter) months, the use of management techniques, such as straw bales, silt fences, and settlement basins is recommended.

The distribution of moderate to highly erodible soils along the proposed alignment within the study area is shown on Figure A26a, through A26e of Appendix A.

Table 5.7-1
Soil Erosion Potential (USDA)

Segment	Station	K-factor	Erosion Potential
Fresno	W Clinton Ave to E Church Ave	0.24–0.37	Moderate
Fresno	E Church Ave to E Central Ave		High
Rural North	E Central Ave to E Davis Street	0.15–0.43	Moderate–High
Rural North	E Davis Street to Highway 43	0.43	High
Rural North	E Barrett Ave to E Harlan Ave	0.32–0.37	Moderate
Kings River Crossing-H	Highway 43 to Denver Ave	0.28–0.37	Moderate
Kings River Crossing-H	King River to Dover Ave	0.37–0.43	Moderate–High
Kings River Crossing-HW	E Harlan to Kings River	0.28-0.32	Moderate
Kings River Crossing-HW	Kings River – Fargo Ave	0.37–0.43	Moderate–High
Hanford Station-H	Fargo Ave to Highway 198	0. 28–0.32	Moderate
Hanford Station-H	Highway 198 to Hanford Armona road	0.43	High
Hanford Station-HW	Fargo Ave to Hanford Armona Road	0.43–0.49	High
Rural Central (majority)	Hanford Armona Ave to Ave 144	0.32–0.49	Moderate–High
Rural Central (minority)	Hanford Armona Ave to Ave 144	0.15–0.28	Low–Moderate
Tule River Crossing	Avenue 144 to Avenue 128	0.32	Moderate
Rural South (Tulare)	Avenue 128 to Avenue 36	0.24–0.49	Moderate–High
Rural South (Tulare)	Avenue 36 to County Line	0.15–0.37	Low–Moderate
Rural South (Kern)	County Line to Airport Road	0.43–0.49	High
Rural South (Kern)	Airport Road to Phillips Road	0.28–0.37	Moderate–High
Wasco and Shafter	Phillips Road to Hwy 58	0.28–0.37	Moderate
Bakersfield North	Hwy 58 to Coffee Road	0.28–0.37	Moderate
Kern River Crossing	Coffee Road to Oak Street	0.28–0.37	Moderate
Bakersfield South	Oak Street to Oswell Street	0.28–0.37	Moderate
Bakersfield South	Oswell Street to Weedpatch Hwy	0.28–0.49	Moderate–High
Bakersfield South	Weedpatch Hwy to Comanche Dr	0.28–0.32	Moderate
Note: High=>0.4, Moderate=0.2-0.4, Low=<0.2			

5.7.1 Subsection FB–A Fresno

The soils along HST Subsection FB–A Fresno from W Clinton Avenue to E Church Avenue have K factors ranging from 0.24 to 0.37 (USDA and NRCS 2008a). The majority of the soil (88%) has a K factor of 0.32. These soils have moderate erosion potential and therefore will require some form of mitigation to ensure that erosion does not become a significant issue (USDA and NRCS 2008a). From E. Church Avenue to E. Central Avenue the soil have a high potential for erosion with K factors ranging from 0.43 to 0.49.

Figure A26a of Appendix A shows the distribution of potentially erodible soils in the Fresno subsection relative to the proposed HST alignment.

5.7.2 Subsection FB–B Rural North

The soils along HST Subsection FB–B Rural North from E Central Avenue to E Davis Avenue (the Hanford-Delhi-Hesperia Association) have K factors ranging from 0.15 to 0.43 (USDA and NRCS 2008a). These soils have moderate to high erosion potential and, therefore, will require some form of mitigation to ensure that erosion does not become a significant issue. The majority of the soils have a K factor of 0.32. The El Peco soil series from north of E Davis Avenue to Highway 43 has a K factor of 0.43, which is considered highly susceptible to erosion and therefore will require some form of mitigation to ensure that erosion does not become a significant issue (USDA and NRCS 2008a).

The Pachappa soil series from E Barrett Avenue to E Harlan Avenue along the HW alignment has a K factor of 0.32 to 0.37, which is considered moderately susceptible to erosion and, therefore, will require some form of mitigation to ensure that erosion does not become a significant issue (USDA and NRCS 2008a).

Figures A26a and A26b of Appendix A show the distribution of potentially erodible soils in the Rural North subsection relative to the proposed HST alignment.

5.7.3 Subsection FB–C Kings River Crossing

The Grangeville and Pachappa soil series, along the HST Subsection FB–C Kings River Crossing H alignment north of the Kings River from Highway 43 to Denver Avenue, have a K factor ranging from 0.28 to 0.37 (USDA and NRCS 2009a). These soils have moderate erosion potential and, therefore, will require some form of mitigation to ensure that erosion does not become a significant issue. The Nord soil series, found between the Kings River and Dover Avenue (south of the Kings River) has a K factor ranging from 0.37 to 0.43. These soils have a moderate to high erosion potential and therefore will require some form of mitigation to ensure that erosion does not become a significant issue (USDA and NRCS 2009a). South of Dover the H alignment traverses the Kimberlina soil series which has a moderate erosion potential ranging from 0.28 to 0.32.

North of the Kings River the HW alignment crosses the Grangeville series which has a moderate potential for erosion and K factors ranging between 0.28 and 0.32. The HW alignment then crosses the Nord soil series south the Kings River. The Nord has a K factor ranging from 0.37 to 0.43. These soils have a moderate to high erosion potential and therefore will require some form of mitigation to ensure that erosion does not become a significant issue.

Figure A26b of Appendix A shows the distribution of potentially erodible soils in the Kings River Crossing subsection relative to the proposed HST alignment.

5.7.4 Subsection FB–D Hanford Station

The soils along HST Subsection FB–D Hanford Station H alignment consist of the Kimberlina series between Fargo and Highway 198. These soils have K factors that range from 0.28 to 0.32 with a moderate potential for erosion. Between Highway 198 and Hanford Armona Road, this alignment traverses the El Peco Series which has a K factor of 0.43, and is considered highly susceptible to erosion and therefore will require some form of mitigation to ensure that erosion does not become a significant issue.

The HW alignment traverses the Nord series which has K factors that range from 0.43 to 0.49 (USDA and NRCS 2009a). These soils have a high erosion potential and therefore will require some form of mitigation to ensure that erosion does not become a significant issue particularly in the vicinity of the Hanford Cut.

Figure A26b of Appendix A shows the distribution of potentially erodible soils in the Hanford subsection relative to the proposed HST alignment.

5.7.5 Subsection FB–E Rural Central

The majority of the soils along HST Subsection FB–E have K factors that range from 0.32 to 0.49 (USDA and NRCS 2009a). These soils have moderate to high erosion potential and therefore will require some form of mitigation to ensure that erosion does not become a significant issue. A small fraction of the soils has a K factor of 0.15 to 0.28, which indicates low to moderate erosion potential (USDA and NRCS 2009a).

Figures A26b and A26c of Appendix A show the distribution of potentially erodible soils in the Rural Central subsection relative to the proposed HST alignment.

5.7.6 Subsection FB–F Tule River Crossing

The soils along the HST Subsection FB–F Tule River Crossing have a K factor of 0.32 (USDA and NRCS 2009b). These soils have moderate erosion potential and therefore will require some form of mitigation to ensure that erosion does not become a significant issue. Figure A26c of Appendix A shows the distribution of potentially erodible soils in the Tule River Crossing subsection relative to the proposed HST alignment.

5.7.7 Subsection FB–G Rural South

Figures A26c and A26d of Appendix A show the distribution of potentially erodible soils in the Rural South subsection relative to the proposed HST alignment. In Tulare County, the soils along HST Subsection FB–G Rural South from Avenue 128 to Avenue 36 (the Gambogy-Biggriz and Gepford-Houser-Armona series) have K factors ranging from 0.24 to 0.49 (USDA and NRCS 2008a). These soils have moderate to high erosion potential. Between Avenue 36 and County Line the Gareck-Atesh-Kimberlina series has low to moderate erosion potential with K factors ranging between 0.15 and 0.37. Erosion control will be necessary in these areas.

In Kern County between County Line and Airport Road the Garces-Panoche soils have high potential for erosion with K factors ranging between 0.43 and 0.49. Kimberlina-Wasco, McFarland, and Milham soil series are found from Airport Road to the end of Subsection G at Phillips Road. These soils have moderate potential for erosion with K factors ranging between 0.28 and 0.37 (USDA and NRCS 2008b). In this section there are possible intrusions of the Garces-Panoche series at both Spangler Road and Sherwood Avenue. Thus this section is rated as having moderate to high potential for erosion, and mitigation measures will be required.

5.7.8 Subsection FB–H Wasco to Shafter

The HST alignment alternatives in Subsection FB-H traverse three surficial soil types: the Kimberlina-Wasco, the Milham, and the Delano-Lewkalb-Drive. These soils all have K factors of between 0.28 and 0.32 with isolated areas in the Kimberlina-Wasco series that have K factors of up to 0.37. Accordingly, this subsection has been classified as having a moderate potential for erosion and will require some form of erosion control (USDA and NRCS 2008b). Figures A26d and A26e of Appendix A show the distribution of potentially erodible soils in the Wasco to Shafter subsection relative to the proposed HST alignment.

5.7.9 Subsection FB–J Bakersfield North

Subsection FB-J, between Hageman Road and Coffee Road, traverses both the Kimberlina-Wasco series and the Milham series and has K factors between 0.28 and 0.37 (USDA and NRCS 200b8). Figure A26e of Appendix A shows the distribution of potentially erodible soils in this subsection. Mitigation measures will be required in this section.

5.7.10 Subsection FB–K Kern River Crossing

The majority of Subsection FB-K traverses the Kimberlina-Wasco series. As shown on Figure A26e of Appendix A, a moderate potential for erosion exists with K factors ranging between 0.28 and 0.37. The majority of this section is within the Kern River bed (USDA and NRCS 2008b). Due to the discharge requirement mandate by the Army Corp of Engineers, the Kern River carries water year round. Figure 5.7-2 shows the discharge released from Isabella Dam in 2006 and 2007 (USGS Water Data Report 2007). The river flow will be the most significant source of erosion in this subsection and moderate potential for erosion exists outside the river bank, thus, requiring erosion control.

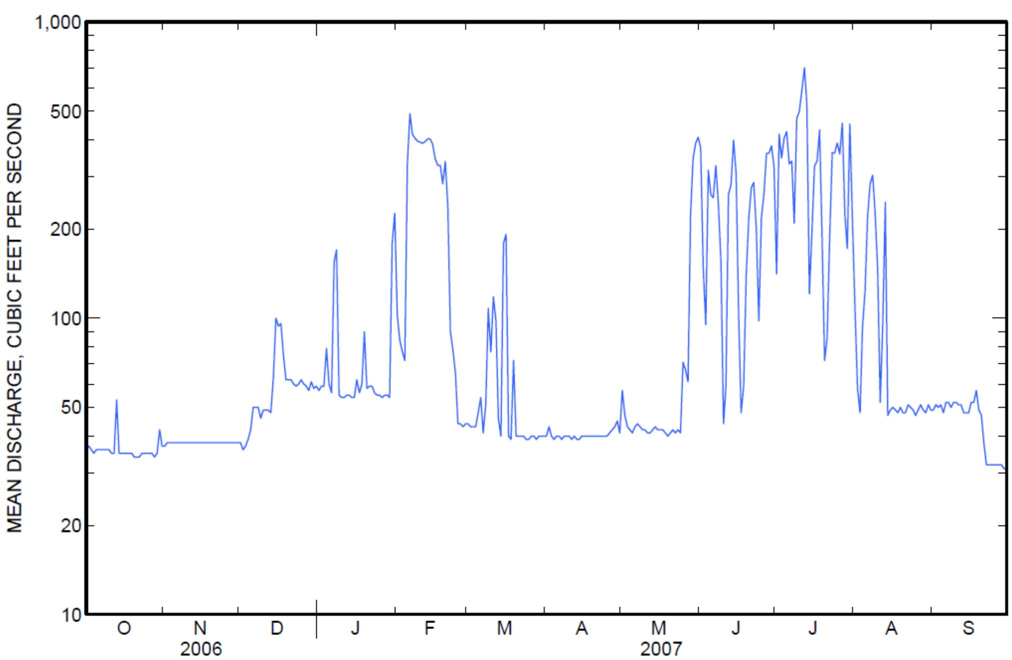

Figure 5.7-2
Kern Canyon Power House Discharge for October 2006 to September 2007 (USGS)

04/02/2014 - RFP No.: HSR13-57

5.7.11 Subsection FB–L Bakersfield South

The Bakersfield South subsection predominantly traverses the Kimberlina-Wasco series west of Washington Street and the Delano-Chanac series east of the same. These soils are classified as moderately susceptible to erosion with K factors ranging between 0.28 and 0.37 (USDA and NRCS 2008b). Between Oswell Street and Weedpatch Highway is the Panoche-Millham-Kimberlina series is moderately to highly erodible having K factors ranging between 0.28 and 0.49 (USDA and NRCS 2008b). Figure A26e of Appendix A shows the distribution of erodible soils along the Bakersfield South subsection. Erosion control mitigation measures will be required in these areas.

5.8 Seasonal Flooding

The relatively flat topography of the SJV contributes to relatively broad, shallow floodplains near the FB Section. Available Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRM) were reviewed to assess the potential flood hazard in the vicinity of the FB Section. FEMA designates Zone A for areas with 1% annual chance of flooding. No depths or base flood elevations are shown in Zone A, because detailed analyses have not been performed in these areas (FEMA 2010). Figure A25 of Appendix A presents the FEMA Zone A flood maps for FB Section. Flood zones in specific subsections are discussed in the following sections of this report.

5.8.1 Subsection FB–A Fresno

Several canals and creeks that contribute to the flood hazard are within the vicinity of Subsection FB–A, including Dry Creek Canal, Central Canal, Dog Creek, Red Bank Slough, and Fancher Creek. The five waterways may combine during large rainstorms to exceed the city of Fresno's drainage system (URS/Arup/HMM 2010). Along the Subsection FB–A alignment, FEMA flood zones are approximately located between E Clinton Avenue and W Olive Avenue, between N Vagedes Avenue and El Dorado Street, between Tuolumne Street and Kern Street, and between S Cherry Avenue and E Jensen Avenue.

5.8.2 Subsection FB–B Rural North

Review of FEMA flood maps indicates that there are no flood zones in Subsection FB–B.

5.8.3 Subsection FB–C Kings River Crossing

Review of FEMA flood maps indicates that flood zones are present in Subsection FB–C in the vicinity of the Kings River.

5.8.4 Subsection FB–D Hanford Station

Review of FEMA flood maps indicates that no flood zones are present in Subsection FB–D.

5.8.5 Subsection FB–E Rural Central

Review of FEMA flood maps indicates that FEMA flood zones are present in Subsection FB–E beginning at Kansas Avenue and extending 3 miles south.

5.8.6 Subsection FB–F Tule River Crossing

Review of FEMA flood maps indicates that FEMA flood zones are present in Subsection FB–F in the vicinity of the Tule River.

5.8.7 Subsection FB-G Rural South

Within Subsection FB-G there are several canals and creeks that contribute to the flood hazard including Poso Creek, County Line Creek, and Deer Creek. FEMA flood zones are approximately located at Avenue 128 to Avenue 98; Avenue 52 to ½ mile south of Tulare/Kern County Line Road and; Avenue 12 to ½ mile south of Woollomes Avenue.

5.8.8 Subsection FB-H Wasco and Shafter

Review of FEMA flood maps indicates that there are minor flood zones in Wasco and Shafter proper; about 4.5 miles south of Shafter in the vicinity of Chrome, CA from Paso-Robles Highway to Poso Ave.

5.8.9 Subsection FB-J Bakersfield North

Review of FEMA flood maps indicates that there are no flood zones in Subsection FB-J.

5.8.10 Subsection FB-K Kern River Crossing

Review of FEMA flood maps indicates that FEMA flood zones are present in Subsection FB-K between approximately Coffee Road and Truxton Avenue in the Kern River flood plain.

5.8.11 Subsection FB-L Bakersfield South

Review of FEMA flood maps indicates that there are flood zones in Subsection FB-L in the vicinity of Edison.

5.9 Scour

Scour analyses are needed to determine the depth of bridge abutments and piers. Generally, the procedures and guidelines presented in the FHWA Evaluating Scour at Bridges, HEC-18, should be followed for this purpose. This document is typically referred to as “HEC-18.” Any crossing of or encroachment onto a natural river, stream, creek, unlined canal, or floodplain along the alignment calls for an evaluation of the scour potential and of the stability of the stream. Crossings where scour analyses should be performed to determine the performance of the proposed structures include the following:

- Kings River.
- Kaweah River.
- Tule River.
- Kern River.
- Poso Creek.
- Creek at County Line.
- Deer Creek.
- Cross Valley Canal.
- Farmers Canal.

Figure A25 of Appendix A shows the locations of these rivers and the FEMA designated Zone A floodplains for the FB Section.

The analysis of scour potential at a bridge or other HST facility should consider several scour components, generalized as follows (HEC-19 1993):

- Long-term bed elevation change.
- General scour.
- Contraction scour.

- Local scour.

5.9.1 Long-Term Bed Elevation Change

As defined in the HEC-20 (1995) report aggradation and degradation are the vertical raising and lowering, respectively, of the streambed over relatively long distances and time frames. Such changes can be the result of both natural and man-induced changes in the watershed.

Long-term bed change can occur in perennial streams that flow year round and in ephemeral desert arroyos. Its progression can take many forms, such as headcuts (vertical channel bed discontinuities) migrating upstream, progressive incision of a low-flow channel, or gradual lowering or raising across the streambed over time. Evaluation of the potential for long-term aggradation or degradation must consider the effects of a range of flow conditions over a long period of time, rather than focusing solely on the effect of a single event. Given the documented, ongoing occurrences of land subsidence in the Bakersfield area and throughout alignment this type of scour analysis may be warranted.

5.9.2 General Scour

General scour is a lowering of the channel bed elevation due to the natural downstream sediment transport capacity of a stream. Physical changes to the stream environment are not required to produce general scour. Common examples of general scour that occur naturally are scour at the outside of a channel bend, scour at a confluence of two streams, and scour that occurs due to a change in stream gradient. For design purposes, general scour is usually evaluated on an event-specific basis, considering one or more flood conditions.

5.9.3 Contraction Scour

Contraction scour is a specific type of general scour that results when the flow area is constricted, for example when a bridged waterway has less flow area under the bridge than upstream. Its effects are usually localized in the vicinity of the constriction. Contraction scour is event-specific and is usually analyzed for one or more flood conditions (e.g., the stability design flood and check flood).

5.9.4 Local Scour

The scour caused by and/or in the immediate vicinity of an obstruction such as a bridge pier or abutment is referred to as local scour. Local scour can also be caused by other localized conditions, such as high-velocity flow impinging on a wall, sudden drops, or scour at the tip of a spur. Local scour is usually evaluated on an event-specific basis considering one or more flood conditions (e.g., the stability design flood and check flood).

5.10 Slope Instability

5.10.1 Landslides

Landslides occur as a result of the downward and outward movement of masses of loosened soil, rock, and vegetation under gravitational forces. Landslide susceptibility depends in part on slope steepness, material type and properties, water content, and amount of vegetation. Landslides may be in the form of fast-moving debris flows or slow-moving soil creep.

In general, the SJV consists of relatively flat terrain that does not contain the requisite topographic features to produce a significant landslide hazard. The lack of steep slopes within close proximity to the HST alignment make landslides and/or debris flows a low potential hazard. Still, there is a potential for localized small slides and minor slumps where the HST alignment

crosses steeper river banks and creeks. Structures located at the top or toe of slopes, such as road embankments or bridge abutments near river banks are most likely to experience damage as a result of slope instability.

Hazard mitigation plans from Fresno and Kings Counties have been reviewed to identify areas near the FB Section that may be susceptible to slope instability. Review of the Fresno County MHMP indicates areas in the foothill and mountain regions of the County where relatively steep slopes and unconsolidated, weathered soils are susceptible to instability. According to the Kings County MHMP, the only significant landslide hazard exists in the southwestern area of the County, including Kettleman Hills, where steeper slopes are present, located away from the alignment.

As detailed in the MBGP (2002) slopes subject to failure in the Bakersfield area are predominantly found along the river terraces, bluffs, and foothills to the northeast and east of the city. Investigations have documented two landslides in the foothills northeast of the city in the vicinity of the Kern River State Park, about 6.5 miles due north of the Town of Edison, located away from the alignment.

In general, these types of geologic terrains do not exist in the relatively flat-lying, urbanized areas in the study area. A site-specific GI, including SPTs and CPTs, is necessary to evaluate in situ soil type, strength, relative density, water content, organic matter, and other properties related to slope stability.

5.10.2 Mass Wasting

Mass wasting depends on steepness of the slope, underlying geology, surface soil strength, and moisture in the soil. Slumps, debris flows, rock falls, and landslides are common forms of mass wasting. Soil and regolith remain on slopes only while the gravitational forces are unable to overcome the frictional forces keeping the material in place. Factors that reduce the frictional resistance relative to the down-slope forces, and thus initiate slope movement, can include the following:

- Seismic shaking.
- Increased overburden from structures.
- Increased soil moisture.
- Reduction of roots holding the soil to bedrock.
- Undercutting of the slope or embankment by excavation, erosion, or scour.
- Weathering by frost heave.

Significant excavating, grading, or fill work during construction might introduce mass wasting hazards along the alignment routes. Apart from crossings at creeks or rivers along the alignment during flooding, seismic event or significant precipitation events, because the alignment within the study area is relatively flat and either above or at-grade, the potential for direct impact from mass wasting at the site is low. If significant excavations are identified during ensuing design phases, these may be an additional sources for mass wasting events that would require additional consideration.

5.11 Hazardous Minerals

Hazardous minerals may be formed from both natural geologic processes and as a byproduct of industrial mining activities. The CGS provides maps and geologic information concerning the occurrence of hazardous minerals throughout California. The CGS lists asbestos, mercury, and radon as three of the more common hazardous geologic minerals that may be found in the state. This report considers naturally occurring hazardous materials. A report describing the hazardous

materials affecting the alignment due to anthropogenic reasons is being prepared as part of the EIR/EIS assessment.

5.11.1 Asbestos

Naturally occurring asbestos (NOA) tends to occur in mafic or ultramafic rock or sediments derived from ultramafic rock. The CGS (2008) website provides current maps that depict where NOA is most likely to occur. Evaluations are performed in accordance with CGS (2002) Special Publication 124 for geologic evaluations of NOA. Exposure and disturbance of rock and soil that contains NOA can result in the release of fibers to the air and consequent exposure to the public. Threshold values and mitigation requirements are provided by the California Air Resources Board (CARB) for quarrying, earthwork, and surface mining operations in the Asbestos Airborne Toxic Control Measure (ATCM 2004).

In California, asbestos containing rock types are predominately, but not exclusively, found in serpentine and ultramafic rocks, which are common in the Sierra Nevada, Coast Ranges, and Klamath mountains (Swaze 2004). Ultramafic igneous rocks are metamorphosed or altered into serpentinites and generally contain 90% dark-colored silicate minerals rich in iron and magnesium (Churchill et al. 2000).

Serpentine rock is primarily composed of one or more types of magnesium silicate minerals. The three most common of this group of minerals are lizardite, chrysotile, and antigorite. Of these minerals, chrysotile is made up of fibrous hairlike crystals. It is a metamorphic and/or magnesium-rich igneous rock from the earth's mantle (CGS 2002). Serpentine rocks are found generally as regional linear bands in the Coast Range Mountains of California from the Oregon border to Santa Barbara County. These rock types are also present along the western side of the Sierra Nevada Mountains from the north central part of the state to Tulare County (Churchill and Hill 2000).

In the early 1900s two deposits in Kern County were reported to contain asbestos. One, about 60 miles west of the Bakersfield near Jawbone Canyon, is reported to contain chrysotile asbestos in serpentine; the other, about 20 miles south of Bakersfield near San Emigdio Canyon is reported to contain amphibole asbestos (DMG 1962). A third documented potential deposit of asbestos in Kern County is about one mile south of the alignment along Highway 58 about 10 miles east of the east end of the study area (DMG 2000).

The results of this mineral study and a review of USGS maps of *Areas More Likely to Contain Naturally Occurring Asbestos* (Churchill and Lee 2000) does not indicate the presence of NOA near the FB Section within the study area.

The presence of asbestos from man-made activities could affect the project. Once the final route alignment is decided, a specialist in this field should assess any buildings or landfills near the alignment for the presence of asbestos.

5.11.2 Radon

Radon gas is a naturally occurring, radioactive gas that is invisible and odorless. It is formed as part of the normal radioactive decay of uranium. Small amounts of uranium occur naturally in rock, typically between 1 and 3 ppm (Otton et al. 2003). As much as 100 ppm of uranium may be found in light-colored volcanic rocks, granites, dark shales, and sedimentary rocks containing phosphate (Otton et al. 2003).

According to the US Environmental Protection Agency (EPA) Radon is the second leading cause of lung cancer according to the US Surgeon General. It forms from the radioactive decay of small amounts of uranium and thorium naturally present in rocks and soils. Radon gas may be harmful

if concentrated in enclosed spaces where ambient conditions are not available to disperse the gas. Radon is most commonly associated with plutonic rocks and shale.

The US Environmental Protection Agency (EPA) and the USGS have evaluated the radon potential in the United States and have developed a map (see Figure 5.11-1) to assist federal, state, and local organizations to target their resources and to assist building code officials in deciding whether radon-resistant features are applicable in new construction. This map is not intended to be used to determine if a home in a given zone should be tested for radon. Homes with elevated levels of radon have been found in all three zones. The map assigns counties to one of three zones based on radon potential. Each zone designation reflects the average short-term radon measurement that can be expected to be measured in a building without the implementation of radon control methods. The average short-term radon measurement associated with each zone in picocuries per liter (pCi/L) is as follows:

- Yellow – Low Risk less than 2 pCi/L.
- Orange – Moderate Risk between 2 and 4 pCi/L.
- Red – High Risk greater than 4 pCi/L.

The average ambient outdoor radon level is 0.4 pCi/L. The average national indoor radon level is 1.3 pCi/L. The EPA's Citizens Guide to Radon website the EPA suggests remediation be considered for levels between 2 and 4 pCi/L and that remediation is warranted for radon levels over 4 pCi/L. Reducing radon levels below 2 pCi/L is difficult.

Figure 5.11-1
EPA Map of Radon Zones in California (EPA 2012)

According to the EPA, all of Fresno, Tulare, and Kern County is in Zone 2 (orange), which means there is a moderate (2 to 4 pCi/L) potential for radon contamination in these three counties. The average indoor radon level for Fresno County, as determined by radon test results published on the California Radon Officer's website, is 2.0 pCi/L with about 13% of the structures surveyed having more than 4 pCi/L. In Kings County, the Radon Officer's website has not published the average level, but 69% of the structures surveyed had radon levels less than about 2.0 pCi/L, and about 11% of the structures surveyed had more than 4 pCi/L. According to the State Radon Officer's website, the average indoor radon levels of Kern County, as determined by radon test results from Air Chek, Inc. is 2.5 pCi/L, and about 13% of the structures surveyed had more than

4 pCi/L. In Tulare County, the average level is about 2.6 pCi/L, and about 23% of the structures surveyed had more than 4 pCi/L. Reducing radon levels below 2 pCi/L is difficult.

5.11.3 Mercury

Mercury exists in the environment from both natural processes and human activities. Natural sources include volcanoes, hot springs, and natural mercury deposits; human-created sources within California are typically the result of coal mining activities (CGS 2010). Naturally occurring mercury is present in the western foothills of Fresno County, but is not currently being mined (Fresno County GPBR 2000). Naturally occurring mercury is present in the western foothills of Kern County and in the San Emigdio Mountains, but is not currently being mined. Because extensive mining activity is not present in the vicinity of the FB Section, hazards associated with the occurrence of mercury are considered low.

Man-made sources of mercury are possibly associated with industries, such as chemical works, petrochemical plants, and refineries. Once the final route alignment is decided, a specialist in this field should assess any industries past or present, adjacent to or upstream of the proposed alignment, for the presence of activities associated with mercury.

5.12 Abandoned Mines and Karst Terrain

5.12.1 Abandoned Mines

Luther (2007) describes the hazards associated with abandoned mines to be either physical and environmental or chemical hazards. Physical hazards include the mine workings themselves, derelict structures, and mining-related equipment. Open shafts descending tens to thousands of feet are particularly hazardous. Chemical or environmental hazards presented by abandoned mine lands include increased stream sediment, mercury pollution, acid mine drainage, asbestos problems, and other negative impacts on water and soil quality (Luther 2007).

Collapsing underground abandoned mine workings represent another physical hazard that can occur at any time. If the mine workings are near the ground surface, subsidence may occur. Although the potential for this type of physical hazard can be more difficult to predict, several instances of abandoned mine-related subsidence have occurred in recent years in California (Luther 2007).

Kern County has an estimated 4,498 abandon mines while Tulare County has 262. According to the publication Mines and Mineral Resources of Kern County, CA (DMG 1962), the County of Kern contains, but is not limited to, the following mineral resources: boron, clay, gold, gypsum, limestone for cement, roofing-granule material, silver, and tungsten. Most of the gold and silver deposits have been mined from the southeastern portion of Kern County (PdV EIR 2007).

Although portions of Kern and Tulare County are rich in mineral deposits, the study area does not traverse any known mineral resources of statewide or regional importance. There are no mining districts located in the proposed project site.

It should be noted that the aerial photography interpretation (see Appendix B for further discussion) noted the presence of inundated gravel pits (and landfills) adjacent to the alignment where the alignment crosses South Chestnut Avenue, approximately four miles south of Boules. Historical unrecorded pits may be present along the alignment which may have been backfilled in an uncontrolled manner.

5.12.2 Karst Terrain

Carbonate rocks such as limestone, composed mostly of the mineral calcite ($CaCO_3$) are very susceptible to dissolution by groundwater during the process of chemical weathering. Such dissolution can result in systems of caves, sinkholes, and eventually to Karst topography (earthsci.org). Subsidence occurs with the collapse of overlying materials into large underground cavities. Although the processes that cause this type of subsidence generally occur in limestone bedrock below the soil zone, collapse of the surface soils into the voids below is the usual surface manifestation. Karst terrain is typically uncommon in California although some efforts to remediate sinkholes at the University of California, Santa Cruz, Earth and Marine Sciences Building using compaction grouting.

Available USGS Karst maps do not indicate the presence of Karst topography in the SJV. Because materials underlying the SJV are primarily Quaternary sedimentary deposits, it is unlikely that Karst topography will be encountered along the FB Section.

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Section 6.0

Geologic Resources

04/02/2014 - RFP No.: HSR13-57

6.0 Geologic Resources

6.1 Mineral Resources

The CGS classifies the regional significance of mineral resources in accordance with the SMARA of 1975 and assists the CGS in the designation of lands containing significant aggregate resources. These resources are typically aggregate resources (sand, gravel, and rock suitable for crushing) used extensively in the construction industry. Mineral Resource Zones (MRZs) have been designated to indicate the significance of mineral deposits. The MRZ categories are as follows:

- MRZ-1: Areas where adequate information indicates that no significant mineral deposits are present or where it is judged that little likelihood exists for their presence.
- MRZ-2: Areas where adequate information indicates significant mineral deposits are present, or where it is judged that a high likelihood exists for their presence.
- MRZ-3: Areas containing mineral deposits the significance of which cannot be evaluated from available data.
- MRZ-4: Areas where available information is inadequate for assignment to any other MRZ.

The MRZ classifications are applied based on available geologic information, including geologic mapping and other information on surface exposures, drilling records, and mine data. The designations are also based on socioeconomic factors, such as market conditions and urban development patterns. Local agencies are required to use the classification information when developing land use plans and when making land use decisions.

Based on map MS 52 produced by CGS entitled *Aggregate Availability in California* and other resources there are no significant existing sand and gravel quarries within the study area. However, Figure A27 of Appendix A indicates there are areas adjacent to the alignment that may have served as historical quarries and/or borrow areas.

Information on the mineral resource potential within the Fresno portion of the study area was obtained from the California Division of Mines and Geology (now the CGS), Generalized Mineral Land Classification of Aggregate Resources in the Fresno Production-Consumption (P-C) Region (CDMG 1988b). In accordance with California's SMARA, the land in the Fresno P-C Region is classified according to "the presence, absence, or likely occurrence of significant mineral deposits in areas of the county subject to either urban expansion or other irreversible land uses incompatible with mining." Review of a CGS map of Aggregate Availability in California (Kohler 2006) indicates permitted aggregate resources of 629 million tons in Fresno, 117 million tons in northern Tulare County, and 88 million tons in southern Tulare County.

Surface mining of sand and gravel in Fresno County occurs primarily along the San Joaquin River between, approximately Firebaugh to the west and Friant to the east, and along the Kings River between approximately Pine Flat Lake to the north and Reedley to the south. According the Fresno County General Plan Background Report (2000), these aggregate resources have been nearly depleted along the San Joaquin River and more production has been shifted to the Kings River. Aggregate resources in the area are expected to supply regional demand until approximately 2011. The San Joaquin River Resource Area and the Kings River Resource Area (about 1 mile and over 15 miles east of the FB Section, respectively) are areas within the Fresno study area, which are mapped as MRZ 2.

Within Fresno County, other currently extracted mineral resources include asbestos, granite, gypsum and limestone with past mineral production included chromite, copper, diatomite, gold,

and tungsten however, the location of these sites it is thought to be away from the proposed alignment in the foothills of and/or the central Coastal Range and Sierra Nevada mountain range.

The aerial photography interpretation (see Appendix B for further discussion) noted the presence of inundated gravel pits (and landfills) adjacent to the alignment where the alignment crosses South Chestnut Avenue, approximately four miles south of Boules.

According to the publication Mines and Mineral Resources of Kern County, CA (CDMG 1962), Kern County contains many types of mineral resources, such as boron, clay, gold, gypsum, limestone for cement, roofing-granule material, silver, and tungsten. Most of the gold and silver deposits have been mined from the southeastern portion of Kern County in the Tehachapi mountains.

The CDMG (now CGS) published Special Report 147 (SR 147) – *Mineral Land Classification: Aggregate Materials in the Bakersfield Production-Consumption Region* -originally published in 1988. Special Report 210 published in October 2009 reevaluates and updates SR 147. Sand and gravel deposits having material suitable for use as construction aggregate are classified in this update report. Emphasis was placed on deposits of Portland Cement Concrete-grade (PCC-grade) aggregate; however, permitted deposits suitable for lower grades of aggregate use, such as asphaltic aggregate, base, subbase, and fill were also included. Only PCC-grade deposits were placed in Sectors for potential consideration for designation by the State Mining and Geology Board.

In this update report, the following conclusions are made:

- Currently permitted PCC-grade aggregate reserves are projected to last through the year 2031, 21 years from the present (2010).
- In this update report an additional 2,456 acres of land containing an estimated 442 million tons of PCC-grade aggregate resources are identified in areas adjacent to the Bakersfield P-C Region.
- The anticipated consumption of aggregate in the Bakersfield P-C Region for the next 50 years (through the year 2058) is estimated to be 467 million tons, of which 224 million tons must be PCC quality. This is more than twice the previous 50-year projection.
- An estimated 4,279 million tons of unpermitted PCC-grade aggregate resources are identified in the Bakersfield P-C Region and adjacent areas.

A review of the Bakersfield study area relative to the published update indicates that MRZ- 2 conditions apply to about a 4-mile-long segment of the alternative alignments between the intersection of Highways 99 and 178 (Sta. 6891+00 to Sta. 7150+00). All other portions of the alignment within the Bakersfield P-C area are designated MRZ-3.

Once the final route alignment is selected, a further assessment of the presence (historical and modern) of extractive industries adjacent to the proposed alignment should be carried out.

6.2 Fossil Fuel Resources

Petroleum is a major geologic resource in the SJV (Harden 2004). The SJV has produced millions of barrels of oil and trillions of cubic feet of natural gas since the discovery of these resources more than a century ago (F-B CHSTP SG and GR 2010). Based on the DOGGR estimates, Fresno County alone has over 2,000 oil wells producing over 6 million barrels per year (DOGGR 2008). Fresno County's oil production is located primarily in the area north of Coalinga and near Kettleman City along Interstate CA-5, (Fresno County GPBR 2000).

The proposed alignment of the FB Section's northern section (sub sections A (Fresno) to F (Tule River Crossing) does not have any significant oil or gas fields in proximity. Figure A28 of Appendix A shows the location of oil and gas fields and well heads, with reference to the proposed HST. "Smaller oil fields such as Camden, Riverdale, Van Ness, Burrel, and Helm, are located approximately 5 miles west of the alignment along the Kings River in the vicinity of Riverdale and San Joaquin. Additionally, review of DOGGR maps indicates a small abandoned oil field located in Hanford" (HST EIR/EIS Geology, Soils, and Geologic Resources Report).

The southern study area is in close proximity to numerous active and abandoned oil and gas fields within Kern County, primarily between Allensworth and Bakersfield, as shown on Figure A28 of Appendix A. The alignment is situated within the DOGGR Districts 4 and 5. District 4 includes Kern and Tulare County and District 5 includes Fresno and Kings County.

Four primary oil and gas production fields are within a 5-mile radius of Segments FB-G and FB-H along the HST alignment:

- The Camden, Riverdale, Van Ness, Burrel, and Helm oil fields, located approximately 5 miles to the west within the vicinity of Delano.
- Trico Gas field, approximately 4 miles to the west within the vicinity of Delano.
- Rose oil field, within 100 feet in the vicinity of Wasco.
- North Shafter oil field, approximately 2.5 miles north of the town of Shafter.
- Shafter South East.
- Unnamed shaft (under bypass alignment).
- Rio Bravo.
- Greeley.
- Seventh Standard.

Within the Bakersfield reach of the alignment study area (Sections FB-J, FB-K, and FB-L) the HST alignment also crosses the Rosedale, Fruitvale and Edison oil fields. The Rosedale and Fruitvale fields are approximately 6 and 1.5 miles to the west of Bakersfield, respectively. The Edison field is 6 to 8 miles east of Bakersfield. Reportedly, on the order of 7 active and 4 abandoned wells are within the footprint of the proposed project (URS 2010). These and other potentially obstructive wells need to be properly addressed during the design phase construction.

Hazard mitigation goals associated with the HST's proximity to the identified oil and gas resources along the alignment are to reduce the public's exposure to fire, explosion, blowout, and other hazards associated with the accidental release of crude oil, natural gas, and hydrogen sulfide gas. To protect both the resource and the public, methods of mitigating the hazard during the 30% design phase include conducting a comprehensive study of all wells and extraction delivery systems (i.e., buried pipelines) to ensure that any future subsurface construction activities are sufficiently removed and/or do not disrupt existing or proposed facilities. Obviously, there is a risk of encountering contaminated soils in these areas during construction as well particularly for any element in the immediate vicinity of the well heads. Kern County has or is conducting a survey of areas where there are significant contamination/concentrations of hydrogen sulfide in oil fields. Mitigation measures implemented during construction may require spill prevention and contaminant migration/removal plans.

6.3 Geothermal Resources

The nearest geothermal resource is the Coso Geothermal Field (see Coso Volcanic Field on Figure 5.1-1). This well-known geothermal area is more than 80 miles northeast of Bakersfield. Fumaroles are present along faults bounding the rhyolite-capped horst and locally within the rhyolite field. A multi-disciplinary program of geothermal assessment carried out in the 1970s defined a potential resource of 650 megawatts with a nominal life span of 30 years. Judged by the youthfulness of the rhyolite lavas and by a zone of low seismic velocity crust roughly beneath the rhyolite, a magma body may be the source of thermal energy for the geothermal system. Commercial power development began in the 1980s. Located in the China Lake US Naval Air Weapons Station near Ridgecrest, CA, power plants at the Coso Geothermal Field are currently operated by Caithness Energy, LLC (Reno, NV). The field currently produces 270 MW from four geothermal power plants. More than 100 wells have been drilled throughout the field, with production depths from 2,000 to 12,000 feet (610 to 3,700 m), and with temperatures from 200° to 350°C. Coso began generating electricity in 1987. Since then, improvements have resulted in more efficient use of the resource.

Given the Coso Geothermal Field's distance to the alignment, the HST is unlikely to impact this resource. Based on review of the DOGGR California Geothermal Map (DOGGR 2002a) none of the alternative alignments are located in or near a geothermal resource area as classified by DOGGR. Additionally, no producing or abandoned geothermal wells or geothermal springs are located along the HST alignment within the study area.

6.4 Groundwater

Groundwater refers to precipitation that infiltrates into the ground and is stored within rocks and sediments beneath the ground surface (Harden 2004).

6.4.1 Quality and Accessibility

The quality and accessibility of groundwater is an ongoing concern in the SJV because of continued irrigation for agricultural purposes. High levels of nitrates, pesticides, and herbicides from fertilizers and irrigation run-off have created water quality issues throughout the Great Valley (Harden 2004). Evaporation of irrigation water in the arid climate of the SJV leads to excessively salinity in the groundwater. Large concentrations of boron and selenium have also been found in the area's groundwater (USGS PP 1766).

Two basic groundwater types characterize the groundwater quality in the study area:

- Bicarbonate-rich (HCO_3^-) waters derived from the Sierra Nevada, on the east side of the valley.
- Sulfate-rich (SO_4^{2-}) waters from the Coast Ranges, on the west side of the valley.

Review of the Fresno County GPBR (2000) indicates that most poor quality groundwater is located in the western area of the County. Relatively high concentrations of total dissolved solids (TDS), sodium, sulfate, boron, chloride, selenium, and carbonate/bicarbonate have been found in western Fresno County. Additionally, concentrations of dibromochloropropane (DBCP), a pesticide, have exceeded maximum contaminant levels (MCLs) in eastern Fresno County (Fresno County GPBR 2000).

Arsenic in the Kern fan is one contaminant that derives mostly from natural processes. Erosion in the Sierra Nevada delivers granitic and volcanic rocks that contain arsenic to the alluvial fan, and dissolution of these rocks by moving groundwater liberates the arsenic. Also, ferric hydroxides, abundant weathering products in these types of rocks, adsorb arsenic at low pH (acid conditions) and lose their absorptive properties as pH increases (alkaline conditions). Dissolution of most rocks elevates groundwater pH and stimulates the release of additional arsenic held by ferric hydroxides. Arsenic delivered to the basin by the Kern fan derives from fluid-rock interactions that liberate arsenic from granitic rocks, intermediate volcanics, and ferric hydroxides. Because this arsenic dissipates with difficulty into saline groundwater of the basin, more arsenic enters the system than leaves. This condition results in concentration of arsenic in the mixing zone.

A review of CDWR Bulletin 118 indicates that out of 444 wells tested in the Kern County groundwater basin, 60 had excessive levels of inorganics, radiological constituents, nitrates, pesticides, Volatile Organic Compounds (VOCs) and Semi-VOCs. According to the same bulletin, within the Tule River groundwater basin to the north, out of 73 wells tested, 10 had excessive levels of the same constituents. Additionally, concentrations of various contaminates related to the JR Simplot property have exceeded maximum concentration levels in Edison (GeoMatrix 2006), rendering the groundwater in that area undrinkable.

6.4.2 Depletion and Recharge

Depletion of water in aquifer storage has created competing demands for water resources in the SJV. Consequences of storage water depletion include changes in surface-water quality, quantity, temperature, and land subsidence. Water management strategies such as enhancement in conjunctive, or simultaneous, use of surface water and groundwater, water banking, and withdrawal restrictions have been implemented throughout the SJV to mitigate the problems associated with excessive groundwater pumping (USGS PP 1766). For the most part, these strategies have been successful for the SJV as a whole; however, within the Tulare Basin (which extends from north of Fresno to south of Bakersfield) significant groundwater storage losses persist. The losses are attributable to persistent drought conditions combined with restrictions on pumping from the San Joaquin River and the delta imposed by federal regulations protecting the delta smelt. The restrictions on available water from these two sources have caused catastrophic losses of several hundred thousand acres of farmland and orchards that now lie fallow in the Tulare Basin. The loss of this surface water resource has imposed additional load on groundwater pumping.

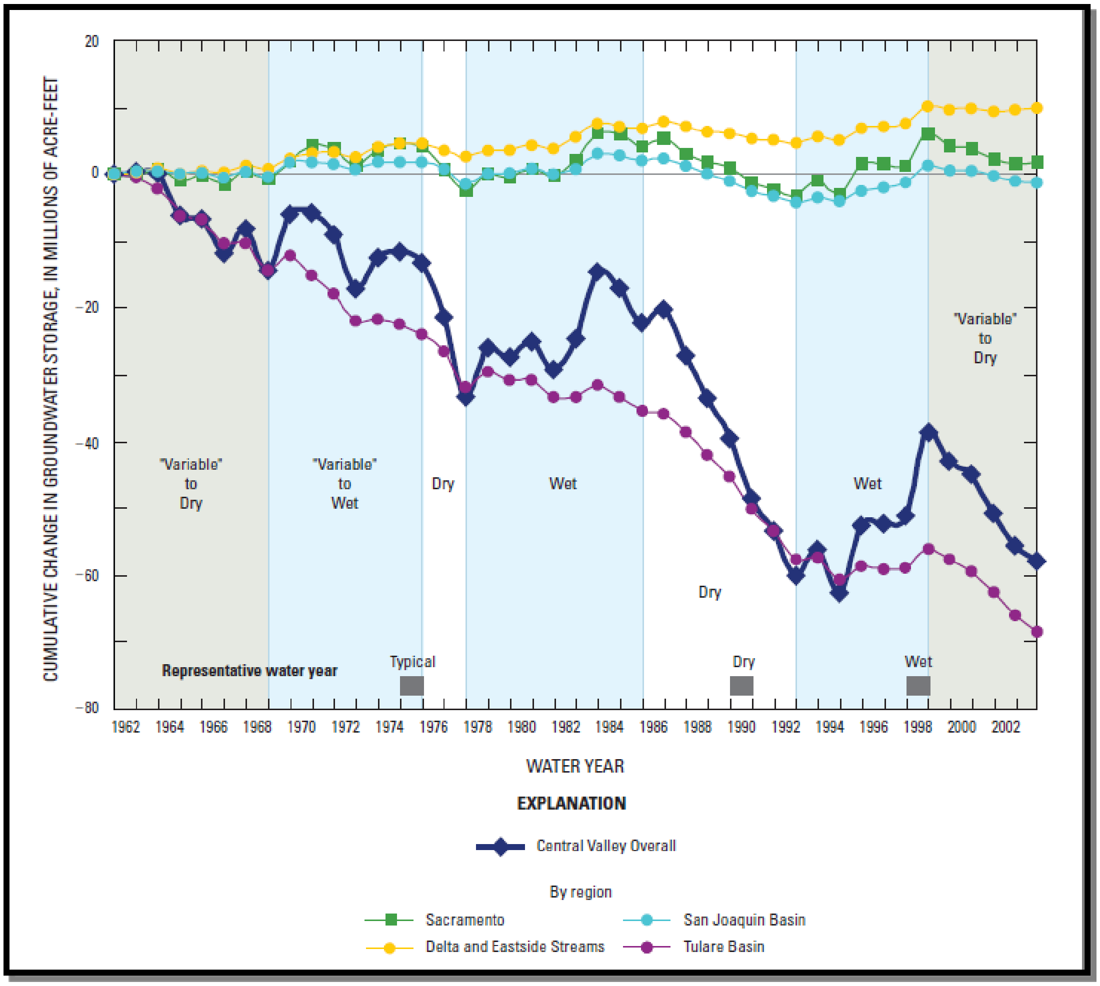

Figure 6.4-1
SJV Groundwater Storage Losses (USGS 2009)

Natural recharge within the Kern Groundwater Sub-basin is primarily from stream seepage along the eastern sub-basin and Kern River. Recharge from applied irrigation water, however, is the largest contributor. The Kern County Water Agency estimates that the total water in storage is 40,000,000 acre-feet and that dewatered aquifer storage is 10,000,000 acre-feet. These estimates apparently consider areas of the subbasin that are known to overlay useable groundwater, and which the agency reports to be about 1,000,000 acres. As shown in Figure 6.4-1, groundwater recharge in the Tule River subbasin is primarily from stream recharge and from deep percolation of applied irrigation water (CDWR, Bulletin 118).

Between 1926 and 1970, groundwater extraction resulted in more than 8 feet of subsidence in the north-central portion of the subbasin, and approximately 9 feet in the south-central area (Ireland et al. 1984). Water banking was initiated in the sub-basin in 1978, and as of 2000, seven projects contained over 3 million acre-feet of banked water in a combined potential storage volume of 3.9 million acre-feet (CDWR, Bulletin 118). Approximately two thirds of this storage is in the Kern River Fan area west of Bakersfield; the remainder is in the Arvin-Edison Water Storage Depocenter in the southeastern sub-basin or in the Semitropic Water Storage Depocenter in the northwestern sub-basin. This is substantially supported by Figure 4.5-1 which shows that the current extent of shallow groundwater in the Kern subbasin covers both of these areas. Both of these areas historically suffered more than 100 feet of groundwater depletion prior to 1970.

Section 7.0

Other Investigations

7.0 Other Investigations

7.1 Site Reconnaissance

The RC performed a preliminary field reconnaissance for three days in May 2010. The walk-through conducted was restricted to areas that were accessible via public right-of-way and, thus, was not comprehensive; access to private property and railroad right-of-way were not granted prior to performing the walk-through.

The RC's site visit included a preliminary assessment of potential exploration locations based on the major structures proposed along the Fresno to Bakersfield HST Section. The findings from this field reconnaissance will be used in planning the preliminary GI, which will support design efforts for the 30% engineering reports.

While subsidence-related ground fissures that developed in the past on the Pond fault have been documented as discussed in Section 3.5.3, the RC was not able to detect any subsidence-related damage during the reconnaissance in this area.

7.2 Additional Subsidence Data – Outreach to Agencies

The RC also reached out to various jurisdictions including Caltrans, CADWR, the United States Bureau of Reclamation (USBR), and the Central Valley Flood Control Board (CVFCB) to determine if any maintenance records documenting infrastructure damage due to regional subsidence were available. During a conversation between the RC and Len Marino, Chief of the Central Valley Flood Control Board, he indicated some well heads had suffered minor damage (August 19, 2013, personal communication). The RC was not able to locate any additional records, anecdotal or hard. Moreover, none of these jurisdictions had any plans to monitor maintenance of infrastructure or damage costs due to subsidence.

The only plans to mitigate subsidence that the RC was able to discover were through the CVFCB, which is a stakeholder along with the San Luis Canal Company and the Central California Irrigation District, and the USBR in the San Joaquin River Restoration Project. These entities are making some provisions to mitigate subsidence within this project by modifying groundwater pumping strategies, e.g., extracting from shallower wells rather than the deeper wells. Again, according to the CVFCB, neither of these jurisdictions is tracking infrastructure damage cost related to subsidence. The USBR indicated that the Sac Dam Replacement Project (which is part of the San Joaquin River Restoration Project) has been indefinitely delayed due to indeterminate costs associated with ongoing subsidence (Michael Mitchener, USBR, Deputy Program Manager, October 4, 2013, personal communication).

Mr. Mitchener of the USBR also informed us of the Subsidence Coordination Group headed up by Valarie Curley (also at the USBR), which consists of various entities and private consultants evaluating subsidence and mitigation alternatives across the SJV.

7.3 Preliminary Aerial Photography Interpretation and Map Review

The counties that the FB Section of the CHSTP passes through — Fresno, Kings, Tulare, and Kern — provided historical aerial photographs to the RC. Features identified were marked and saved as layers within the GIS system. The features were also tagged with the following information: unique feature identification number, feature type, year feature was first identified, year feature was last seen, and a brief description of the feature.

7.4 Archaeological Test Pits

A RC geotechnical representative was on-site to observe nine archaeological test pit excavations (T7, T8, T9, T10, T11, T12, T20, T21, and T22) performed between March 8 and March 10, 2011, as part of the project EIR/EIS studies. A map showing test pit locations is presented in Appendix C. The rationale for selection of archeological test pit locations is provided in the EIR/EIS.

The primary purpose of the archaeological survey was to identify the presence of cultural resources within the footprint of the proposed CHSTP alignments. The RC's geotechnical representative was responsible for collecting soil samples, performing in situ testing, and visually classifying excavated soils for the purposes of geotechnical hazard identification. Test pit logs containing visual soil classifications, in situ test results, and test pit photos are presented in Appendix C.

Test pits excavated during this period were located south of Corcoran near Highway 43. Test pit dimensions ranged from 21 to 24 feet in length, 3 feet in width, and 7.5 to 14 feet in depth. Six test pits (T7, T8, T9, T10, T11, and T12) were excavated near the intersection of Highway 43 and Avenue 120. Three test pits (T20, T21, and T22) were excavated near the intersection of Highway 43 and Avenue 96.

The test pits generally consisted of 1 to 3 feet of fill soil overlying interbedded alluvial soils. Alluvial soils included poorly graded sands, silty sands, lean clays, and low plasticity silts. Cohesive soils ranged from medium stiff to very stiff based upon hand torvane and pocket penetrometer tests.

Groundwater strikes were encountered in three of the test pits (T12, T20, and T21) at depths of between 10.5 and 11 feet. Inflows were estimated to range from less than one to about 5 gallons per minute.

Minor sloughing and caving occurred during excavation in three test pits (T7, T8, and T11) at a depth of approximately 6.5 to 7 feet. This depth corresponds to a layer of dry, poorly graded sand with little to no fines content.

No archeological specimens were identified or recovered from the test pits.

Section 8.0

Conclusions

8.0 Conclusions

This report has been written with reference to the TM 2.9.3: Geologic and Seismic Hazard Analysis Guidelines for the proposed FB Section. The RC team has divided the FB Section between Fresno and Bakersfield into 11 subsections on the basis of topography, anticipated ground conditions, and known location of proposed structures.

This *Geologic and Seismic Hazards Report* is a preliminary screening tool to identify potential seismic and geologic hazards and their associated risks. The available documents reviewed to produce this report were generally regional in nature and did not thoroughly evaluate hazards on a site-specific basis. A comprehensive, quantitative, site-specific evaluation is required to confirm the geologic and seismic hazards. Mitigation of risks associated with each hazard should be based on results from appropriate supplementary GI and on interpretation of laboratory and field test data.

The matrix below (Table 8.0-1) summarizes the level of geologic and seismic hazard based on the review of available data. Each potential hazard was evaluated on a segment-specific basis and was categorized as one of the following hazard levels: Negligible (N), Low (L), Moderate (M), or High (H).

Table 8.0-1
Summary of Geologic and Seismic Hazards

SS Suffix	SS Name	Surface Ground Rupture	Seismically Induced Ground Deformation	Seismically Induced Flooding	Volcanic Hazards	Land Subsidence	Areas of Difficult Excavation	Unstable Soils	Soil Corrosivity	Erodible Soils	Seasonal Flooding	Slope Instability	Hazardous Minerals	Abandoned Mines and Karst
A	Fresno	L	L	L	L	M	M	L-H	M-H	M	M-H	L	L	L
B	Rural North	L	M	L	L	L	L-M	M	M-H	L-H	L	L	L	L
C	Kings River Crossing	L	M	L	L	L	L	M	H	M-H	H	L-M	L	L
D	Hanford Station	L	M	L	L	H	L	M	H	M-H	L	L	L	L
E	Rural Central	L	M	L	L	H	L	L-H	L-H	L-H	M	L	L	L
F	Tule River Crossing	L	H	L	L	H	L	M	H	M	H	L-M	L	L
G	Rural South	M	H	L	L	H	L-M	L-H	H	L-H	M-H	L	L	L
H	Wasco and Shafter	L	H	L	L	H	L	L-M	H	M	M	L	L	L
J	Bakersfield North	L	H	H	L	M	L	L-M	H	M	L	L	L	L
K	Kern River Crossing	L	H	H	L	L	L	L-M	H	M	H	M	L	L
L	Bakersfield South	H	H	M	L	M	L	M	H	M-H	M	L	L	L

N = Negligible   L = Low
M = Moderate   H = High

04/02/2014 - RFP No.: HSR13-57

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Section 9.0

Risk and Opportunity Register

9.0 Risk and Opportunity Register

The geotechnical risk register for the project is included in Table 9.0-1. The risk register should not be considered comprehensive, and other geotechnical risks outlined in this report should be considered. The register should be viewed as a live document, to be further updated, revised, and quantified as the project progresses and as further information becomes available, both for the ground conditions and for route options. Further work is recommended to confirm ground conditions and reduce geotechnical risk to the project. It should be noted that the term *mitigation*, as used throughout this document, does not refer to the CEQA definition, which has very specific legal connotations. Rather, it refers to a more generic engineering concept implying that a potential hazard will be remedied either completely or in part by the application of engineering design and construction processes.

Table 9.0-1
Risk and Opportunity Register

		Register reference	GEO 1 – 15%
Project	California High-Speed Train Project	Job number	131577
Package/Topic	Fresno to Bakersfield – Geological and Seismic Hazards	Design stage	15% Engineering

Remember: (A) Avoid – (R) Reduce – (C) Control and communicate relevant information to others

DATE (+ INITIALS)	AREA/LOCATION OF RISK EXPOSURE	DESCRIPTION OF HAZARD AND RISK EXPOSURE	MITIGATION OF RISK (POTENTIAL OR ACHIEVED)	A	R	C	FURTHER ACTION	BY	STATUS ACTIVE/CLOSED
twb 2/1/2012	Alluvium, San Joaquin Valley	Diachronic stratigraphy – vertical and lateral variability in geological units	Perform ground investigation to define subsurface stratigraphy and develop geologic cross sections			✓	Ground investigation	CHSRA	*ACTIVE*
twb 2/1/2012	Historical infilled river channels old lake beds, e.g., Tule Marshes	Soft, compressible organic soils Shallow groundwater	Perform ground investigation to assess the presence and nature of soft, compressible organic soils; evaluate compressibility characteristics of these soils during Preliminary Engineering for Procurement and final design			✓	Review historical aerial photography, ground investigation	CHSRA	*ACTIVE*

DATE (+ INITIALS)	AREA/LOCATION OF RISK EXPOSURE	DESCRIPTION OF HAZARD AND RISK EXPOSURE	MITIGATION OF RISK (POTENTIAL OR ACHIEVED)	A	R	C	FURTHER ACTION	BY	STATUS ACTIVE/CLOSED
twb 2/1/2012	Tulare and Kern River Formations	Gypsiferous clay	Perform ground investigation to assess the presence of gypsiferous clay; design a drainage system that does not negatively impact the foundation soils			✓	Ground investigation	CHSRA	*ACTIVE*
twb 2/1/2012	Alluvium, San Joaquin Valley	Collapsible soils	Perform ground investigation to assess the presence of collapsible soils; design a drainage system that does not negatively impact the foundation soils			✓	Ground investigation	CHSRA	*ACTIVE*
twb 2/1/2012	Western Fresno County	Mudflow deposits	Perform ground investigation to assess the presence of mudflow deposits; evaluate potential for hydrocompaction in drainage system design			✓	Ground investigation	CHSRA	*ACTIVE*
twb 2/1/2012	San Joaquin Valley	Erodible soils	Perform ground investigation to assess the presence of erodible soils; evaluate strategies for controlling wind and water erosion			✓	Ground investigation	CHSRA	*ACTIVE*
twb 2/1/2012	San Joaquin Valley	Montmorillonite swelling clays	Perform ground investigation to assess the presence of swelling clays; address concerns associated with squeezing of clays during construction			✓	Ground investigation	CHSRA	*ACTIVE*
twb 2/1/2012	San Joaquin Valley	Faults obscured by extensive thickness of sediments	Perform ground investigation to assess the presence of faults			✓	Ground investigation	CHSRA	*ACTIVE*
twb 2/1/2012	Water crossings	Scour / erosion	Perform ground investigation to assess the potential for scour and erosion; perform scour analysis and design for long-term bed elevation changes			✓	Ground investigation	CHSRA	*ACTIVE*

DATE (+ INITIALS)	AREA/LOCATION OF RISK EXPOSURE	DESCRIPTION OF HAZARD AND RISK EXPOSURE	MITIGATION OF RISK (POTENTIAL OR ACHIEVED)	A	R	C	FURTHER ACTION	BY	STATUS ACTIVE/CLOSED
twb 2/1/2012	Water crossings	Piping, softening soils, saturation of loose soils (liquefaction)	Design a drainage system that does not negatively impact the foundation soils; evaluate need for strengthening /densification of weak/loose soils			✓	Ensure design is sympathetic to these hazards	CHSRA	*ACTIVE*
twb 2/1/2012	Water crossings	Approach earthworks causing a dam effect	Investigate the locations of both earthworks and flood potential; design drainage system to reduce potential dam effect; protect earthworks from inundation			✓	Provide adequate drainage	CHSRA	*ACTIVE*
twb 2/1/2012	San Joaquin Valley	Seismically induced ground deformations	Site assessment during the ground investigation phase; design structures to withstand damage from extreme events			✓	Ground investigation	CHSRA	*ACTIVE*
twb 2/1/2012	San Joaquin Valley	N-S / NE-SW compression causing earthquakes	Site assessment during the ground investigation phase; design structures to withstand damage from extreme events			✓	Ground investigation	CHSRA	*ACTIVE*
twb 2/1/2012	San Joaquin Valley	Seismically induced slope instability at the channel crossings	Site assessment during the ground investigation phase; design structures to withstand damage from extreme events			✓	Ground investigation	CHSRA	*ACTIVE*
twb 2/1/2012	San Joaquin Valley	Seismically induced slope instability at dams	Site assessment during the ground investigation phase; design structures to withstand damage from extreme events			✓	Ground investigation	CHSRA	*ACTIVE*
twb 2/1/2012	San Joaquin Valley	Expansive soils	Site assessment during the ground investigation phase; design a drainage system that does not negatively impact the foundation soils			✓	Ground investigation	CHSRA	*ACTIVE*
twb 2/1/2012	San Joaquin Valley	Landfill (register and historical)	Site assessment during the ground investigation phase; develop strategies to address risk from asbestos hazard			✓	Ground investigation	CHSRA	*ACTIVE*

DATE (+ INITIALS)	AREA/LOCATION OF RISK EXPOSURE	DESCRIPTION OF HAZARD AND RISK EXPOSURE	MITIGATION OF RISK (POTENTIAL OR ACHIEVED)	A	R	C	FURTHER ACTION	BY	STATUS ACTIVE/CLOSED
twb 2/1/2012	San Joaquin Valley	Dune sands – loose, compressible soils	Contact local geologist; carry out ground investigation			✓	Ground investigation	CHSRA	*ACTIVE*
twb 2/1/2012	San Joaquin Valley	Contamination / hazardous minerals	Site assessment during the ground investigation phase; excavate and remove soils containing hazardous minerals			✓	Ground investigation	CHSRA	*ACTIVE*
twb 2/1/2012	San Joaquin Valley	Local water storage facilities	Site assessment during the ground investigation phase; develop strategies to address site access constraints			✓	Ground investigation	CHSRA	*ACTIVE*
twb 2/1/2012	Inundation of Tulare, Buena Vista and Kern lake beds	Flooding	Ensure risk is addressed through design by allowing for flood conditions			✓	Ensure design is sympathetic to these hazards	CHSRA	*ACTIVE*
twb 2/1/2012	Creeks, rivers, canals, and sloughs	Inundation from high river flows	Ensure risk is addressed through design by allowing for flood conditions			✓	Ensure design is sympathetic to these hazards	CHSRA	*ACTIVE*
twb 2/1/2012	Creeks, rivers, canals, and sloughs	Inundation from severe precipitation events	Ensure risk is addressed through design by allowing for flood conditions			✓	Ensure design is sympathetic to these hazards.	CHSRA	*ACTIVE*
twb 2/1/2012	Drainage channels	Drainage channel blockage	Silt traps, maintenance			✓	Ensure design is sympathetic to these hazards	CHSRA	*ACTIVE*
twb 2/1/2012	Drainage channels	Soakaways causing piping, softening soils, saturation of loose soils (liquefaction)	Design a drainage system that does not negatively impact the foundation soils			✓	Ensure design is sympathetic to these hazards	CHSRA	*ACTIVE*

DATE (+ INITIALS)	AREA/LOCATION OF RISK EXPOSURE	DESCRIPTION OF HAZARD AND RISK EXPOSURE	MITIGATION OF RISK (POTENTIAL OR ACHIEVED)	A	R	C	FURTHER ACTION	BY	STATUS ACTIVE/CLOSED
twb 2/1/2012	San Joaquin Valley	Ground subsidence due to extraction of fluids or gas	Adopt measures within the design to accommodate differential settlements such as use geotextiles to mitigate differential movements of embankments and abutments; control groundwater levels			✓	Ensure design is sympathetic to these hazards	CHSRA	*ACTIVE*
Hmb 5/15/2012	West Hanford Alignment	Soft organic silts and clays at depth (approx. 20 ft bgs)	Ground investigation, design to avoid foundations in soft, compressible materials			✓	Ground investigation	CHSRA	*ACTIVE*

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Section 10.0

Recommendations

04/02/2014 - RFP No.: HSR13-57

10.0 Recommendations

The identification of the geologic and seismic hazards summarized in this report is limited by the lack of comprehensive and site-specific information along the FB Section. Information on expansive soils, collapsible soils, erodible soils, and soil corrosivity is based upon available NRCS soil survey data that studied shallow soils up to only 5 feet below the ground surface and therefore is of limited value to the engineering likely to be carried out as part of this project. A more comprehensive investigation is required to analyze the potential hazards from deeper soils that will be used as bearing layers for structural foundations along the proposed alignment and that will be excavated for basements etc.

To accurately evaluate the level of hazard from seismically induced ground deformations such as liquefaction, lateral spreading, settlement, and slope instability, a site-specific GI is required. As stated in CGS's *Guidelines for Evaluating and Mitigating Seismic Hazards in California*, "If the findings of the screening investigation cannot demonstrate the absence of seismic hazards, then the more-comprehensive quantitative evaluation needs to be conducted" (CGS 2008). Review of available historical seismic data and ground shaking intensity maps suggest that the seismic hazards along the FB Section are significant and require further investigation.

Unfortunately, the available historical information on ground conditions is not sufficiently near the proposed HST alignment or does not contain all the relevant information required by the RC team to make design recommendations. Historical exploratory borehole logs are acceptable in developing a "regional" ground model for a broad geographical area; however, they are inadequate for specific geotechnical consideration on a right-of-way basis or on a structure-by-structure basis.

The RC requires adequate information about the ground conditions to understand the ground engineering behavior so that economic recommendations can be made for the design of proposed foundation structures. The RC team follows standard procedures of developing a ground model by collating and analyzing publically available GI information or "as built records" from various sources including Caltrans, USGS, local agencies, websites, and published reports. The RC team does not currently have sufficient information to adequately prepare the PE4P Geotechnical Design Memoranda, and therefore, a field investigation program (ground truthing) will be required to confirm, support, and supplement the current research.

As outlined in the *Fresno to Bakersfield Geotechnical Investigation Work Plan for Preliminary Engineering for Procurement* submitted in December 2013, the GI developed by the RC for the proposed FB Section includes the following:

- Geomorphologic and geologic walk-through survey of the proposed alignments.
- Drilling of boreholes to supplement the existing information and define the subsurface stratigraphy from recovered soil samples for description, classification, and laboratory testing.
- In situ CPTs to supplement the results of the boreholes in defining the stratigraphy and to provide information from which the engineering characteristics of the major strata can be evaluated.
- Excavation of trial pits to perform in situ testing such as percolation tests and plate loading tests, and to recover soil samples for laboratory testing.

- In situ geophysical testing to locate the presence, thickness, and extent of any hard layers that could be a constraint to construction; define the electrical characteristics of the ground for electrical grounding; and investigate the location and "capability" of faults crossing the alignment.
- In situ geophysical tests using the suspension velocity method to evaluate the shear wave velocities of the major strata.
- Pressuremeter tests at selected locations to evaluate in situ stresses and elastic properties of selected soil strata and hard pan units.
- Spectral analysis of surface waves, resistivity, and other geophysical and intrusive ground investigation techniques to classify the nature of the faults, hazardous or otherwise, that cross the alignment.
- Installation of vibrating wire piezometers and standpipe piezometers to monitor groundwater levels and to facilitate in situ testing to evaluate the permeability characteristics of the major strata encountered.
- A comprehensive laboratory testing program to characterize the major strata and to develop parameters for the engineering analyses and designs.

Section 11.0

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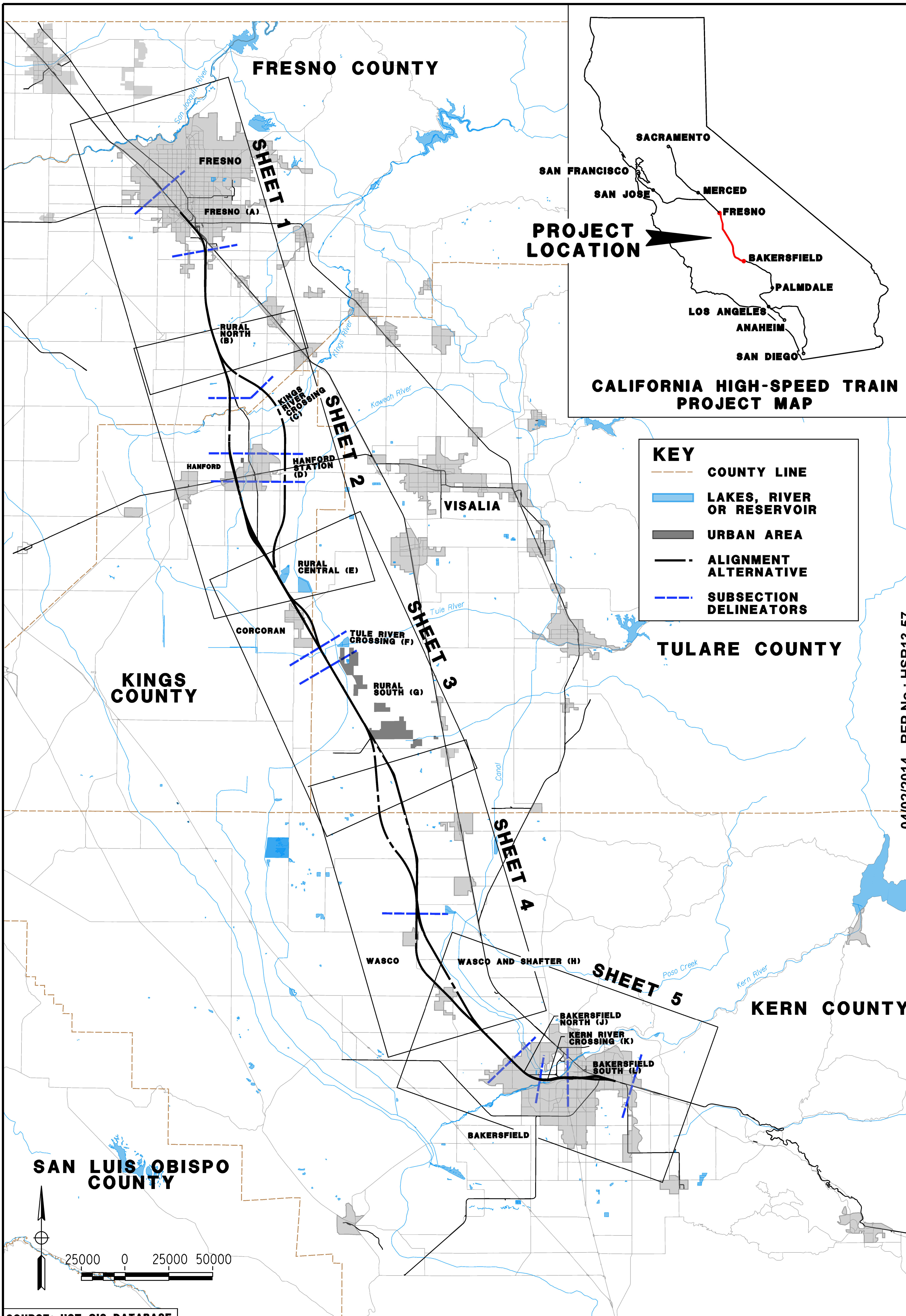
Appendix A

Oversize Figures

Figures



URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
SITE LOCATION PLAN
AND
DRAWING KEY PLAN

FIGURE NO.	A1
DATE	DECEMBER 2013
SHEET NO.	1 OF 1

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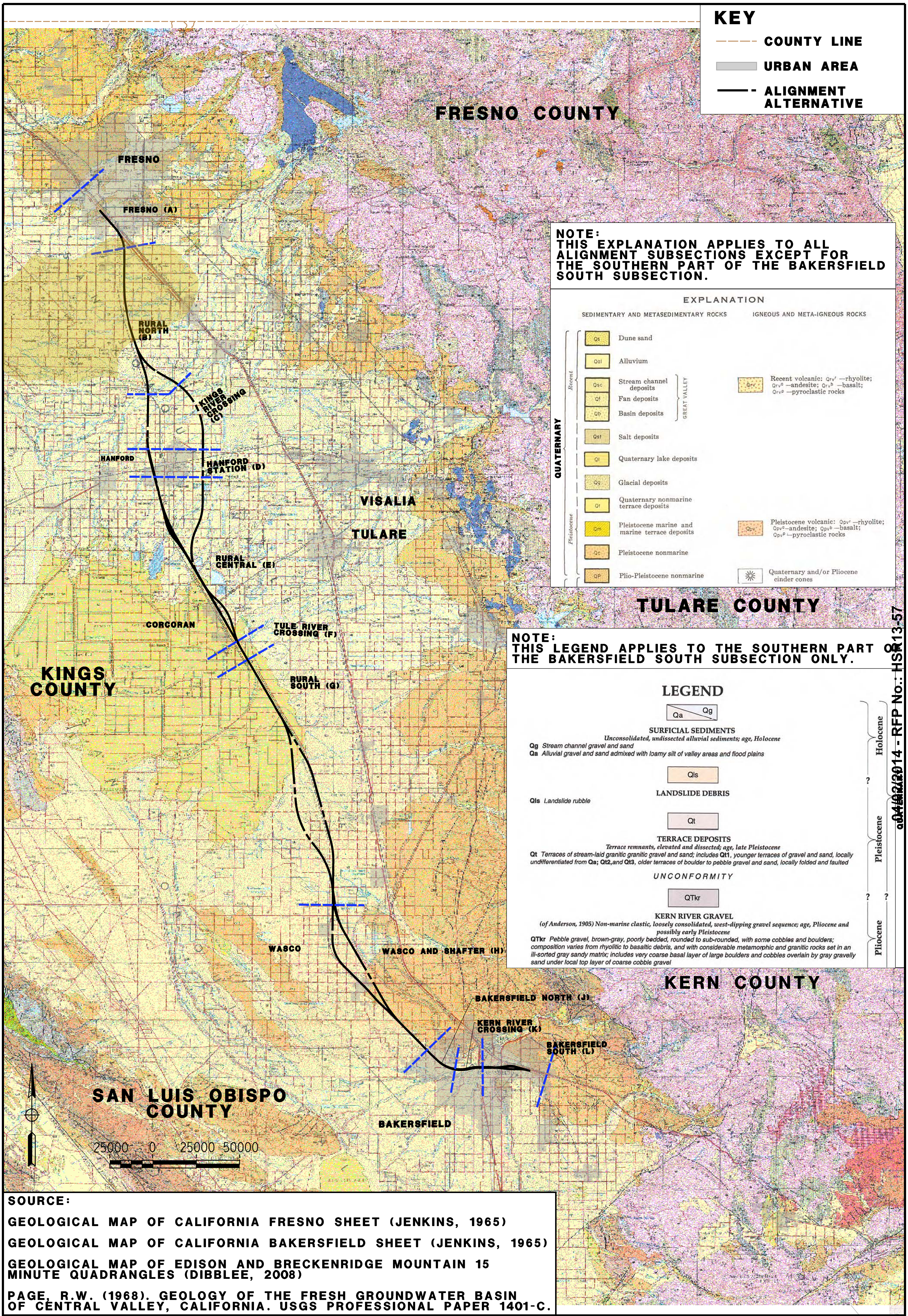

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GEOLOGICAL MAP OF CALIFORNIA BAKERSFIELD SHEET (JENKINS, 1965)

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CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
GEOLOGIC MAP

FIGURE NO. A2
DATE DECEMBER 2013
SHEET NO. 1 OF 1

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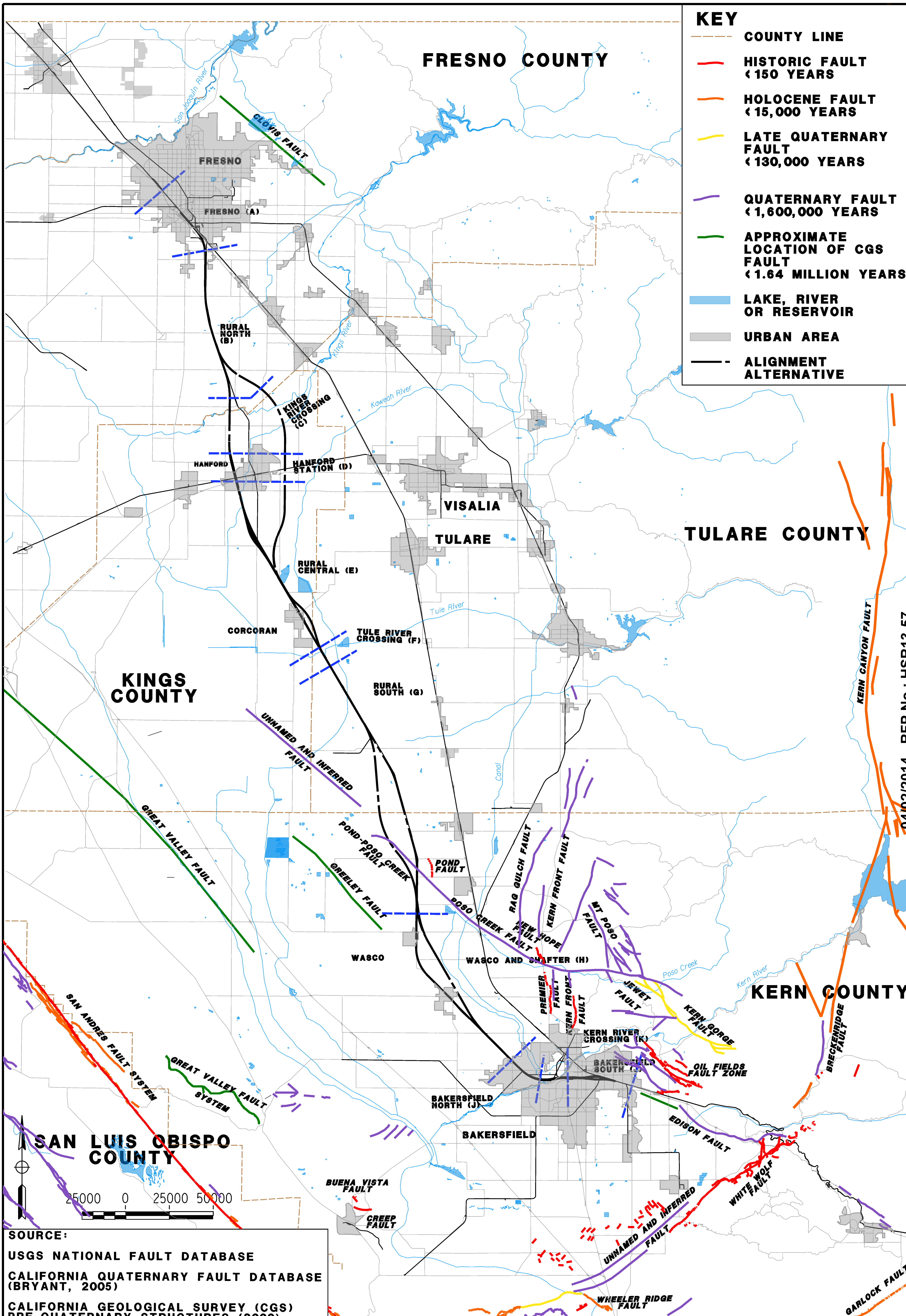

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CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
SIGNIFICANT FAULTS

FIGURE NO.	A3
DATE	DECEMBER 2013
SHEET NO.	1 OF 1

\\global\americas\Jobs\S-F\31000\31577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\2012-01-11_ 15% Seismic & Geological Hazards\FB-GB-6002.dgn
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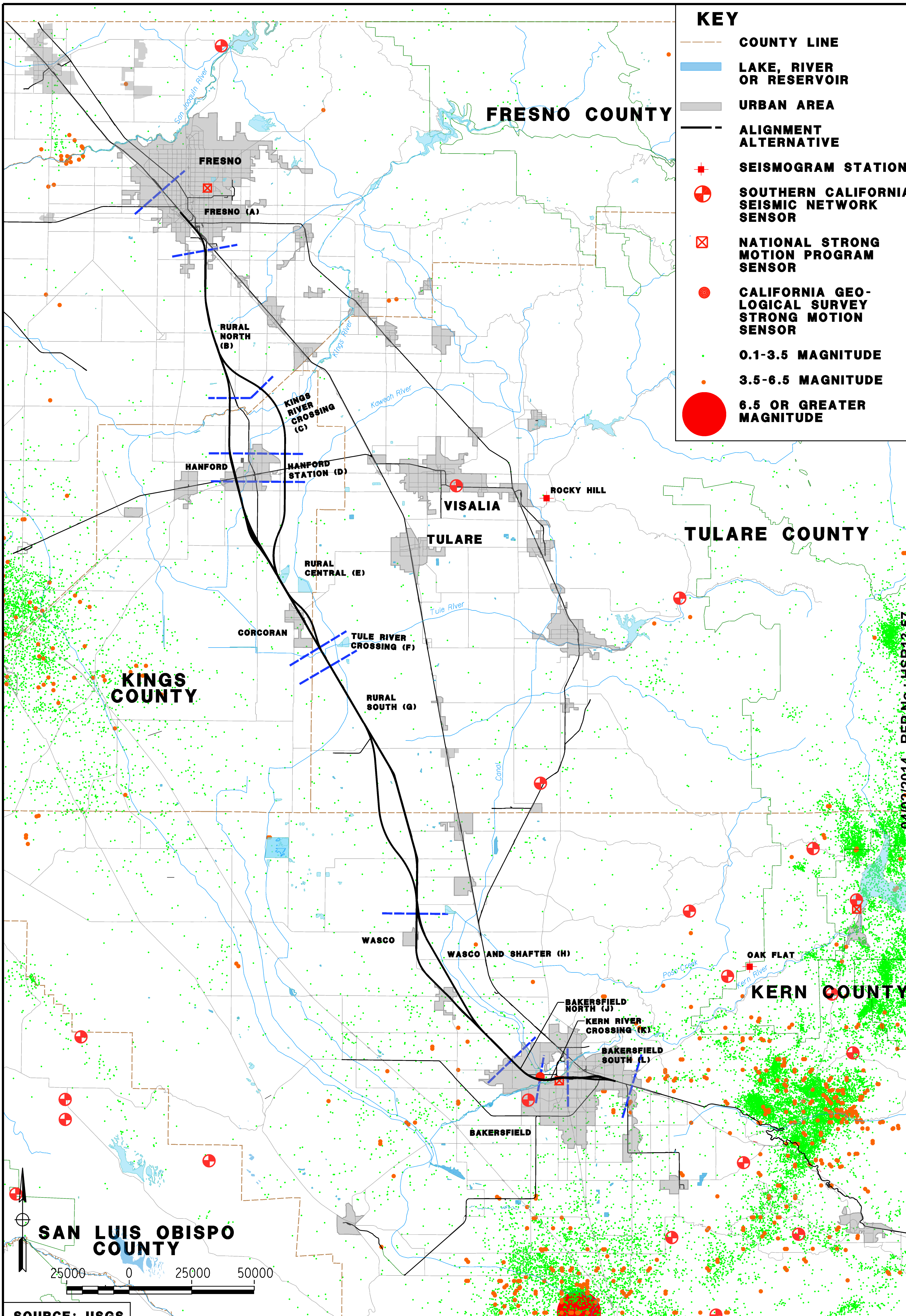

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CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
EARTHQUAKE EPICENTER
AND
MAGNITUDE WITH LOCATION OF SEISMOGRAPHS

FIGURE NO. A4
DATE DECEMBER 2013
SHEET NO. 1 OF 1

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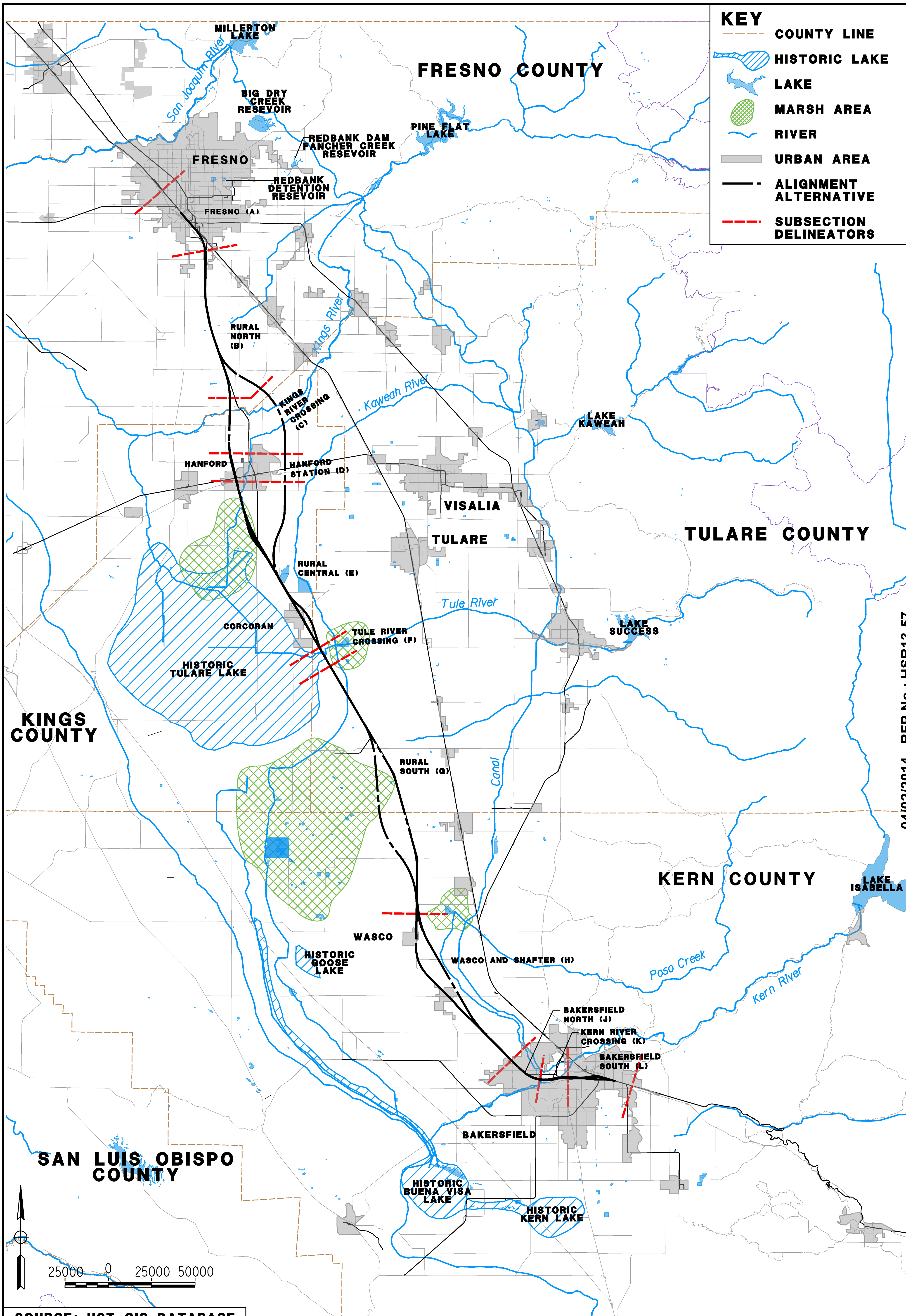

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CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
RIVERS AND LAKES

FIGURE NO.	A5
DATE	DECEMBER 2013
SHEET NO.	1 OF 1

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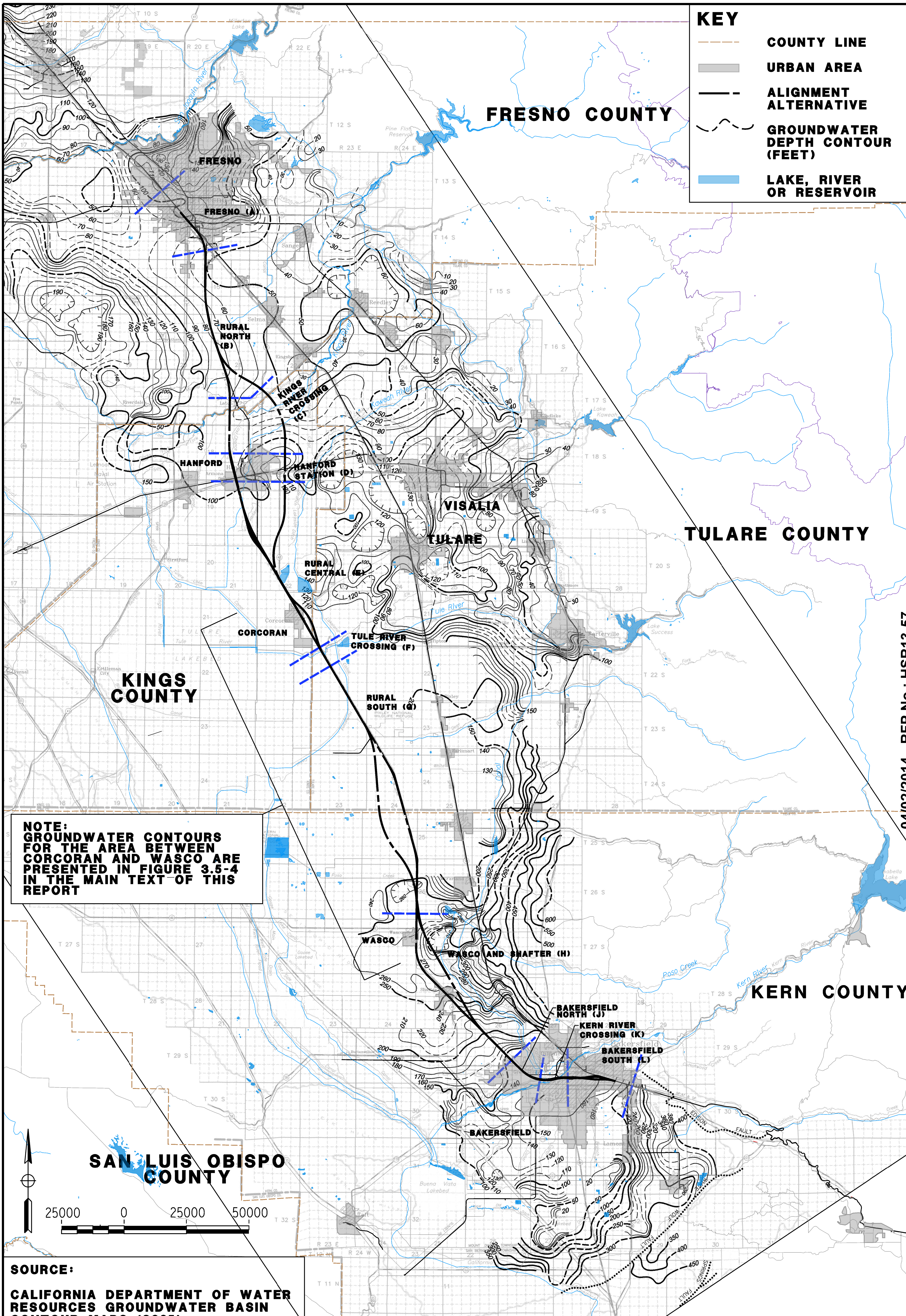

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CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
CONTOURS OF DEPTH TO GROUNDWATER

FIGURE NO.	A6
DATE	DECEMBER 2013
SHEET NO.	1 OF 1

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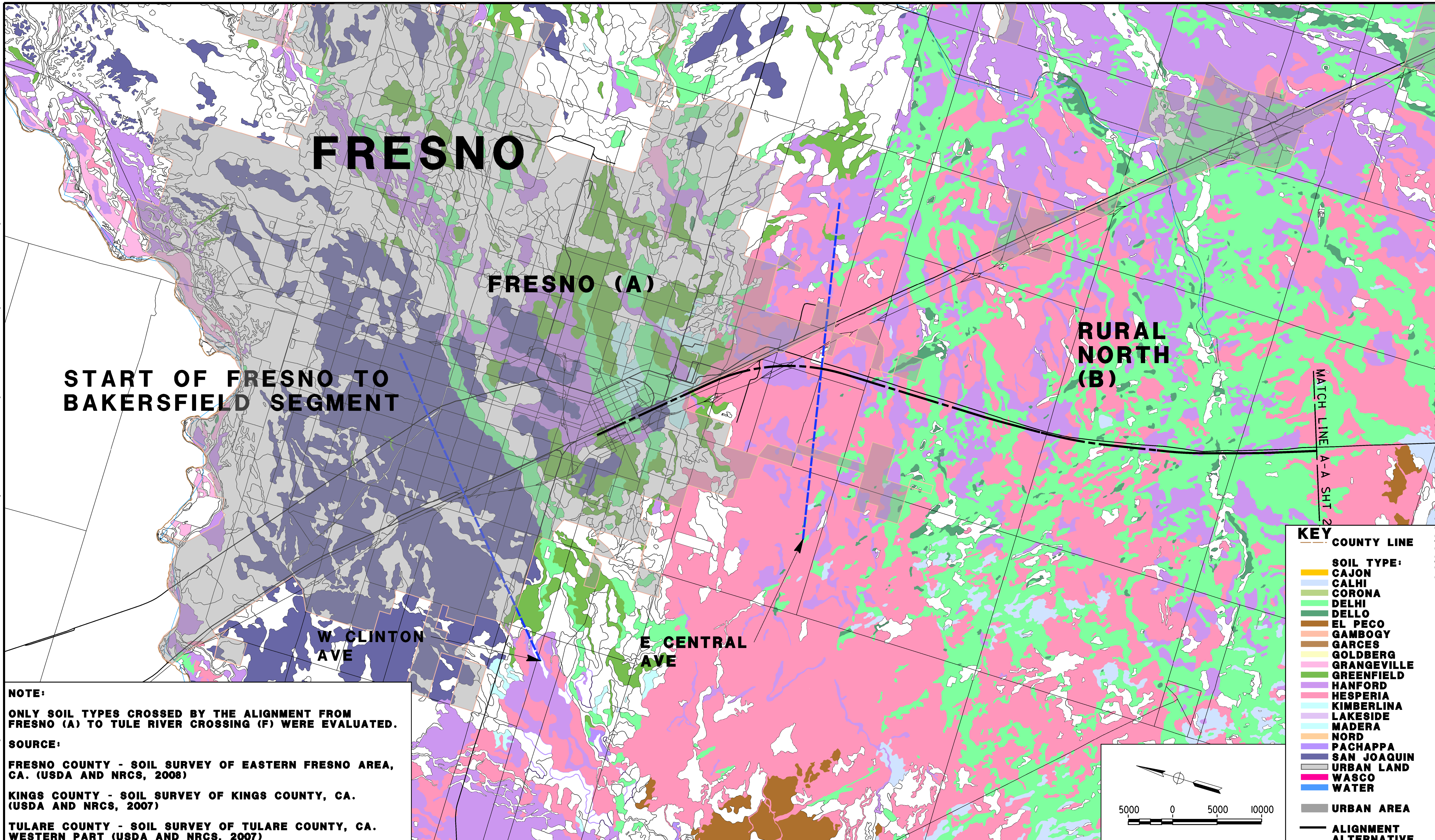

NOTE:

ONLY SOIL TYPES CROSSED BY THE ALIGNMENT FROM FRESNO (A) TO TULE RIVER CROSSING (F) WERE EVALUATED.

SOURCE:

FRESNO COUNTY - SOIL SURVEY OF EASTERN FRESNO AREA, CA. (USDA AND NRCS, 2008)

KINGS COUNTY - SOIL SURVEY OF KINGS COUNTY, CA. (USDA AND NRCS, 2007)

TULARE COUNTY - SOIL SURVEY OF TULARE COUNTY, CA. WESTERN PART (USDA AND NRCS, 2007)

KEY

COUNTY LINE

SOIL TYPE:
- CAJON
- CALHI
- CORONA
- DELHI
- DELLO
- EL PECO
- GAMBOGY
- GARCES
- GOLDBERG
- GRANGEVILLE
- GREENFIELD
- HANFORD
- HESPERIA
- KIMBERLINA
- LAKESIDE
- MADERA
- NORD
- PACHAPPA
- SAN JOAQUIN
- URBAN LAND
- WASCO
- WATER

URBAN AREA

ALIGNMENT ALTERNATIVE

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CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
USDA AND NRCS SOIL SURVEY: FB-A to FB-B

FIGURE NO.	A7a
DATE	DECEMBER 2013
SHEET NO.	1 of 3

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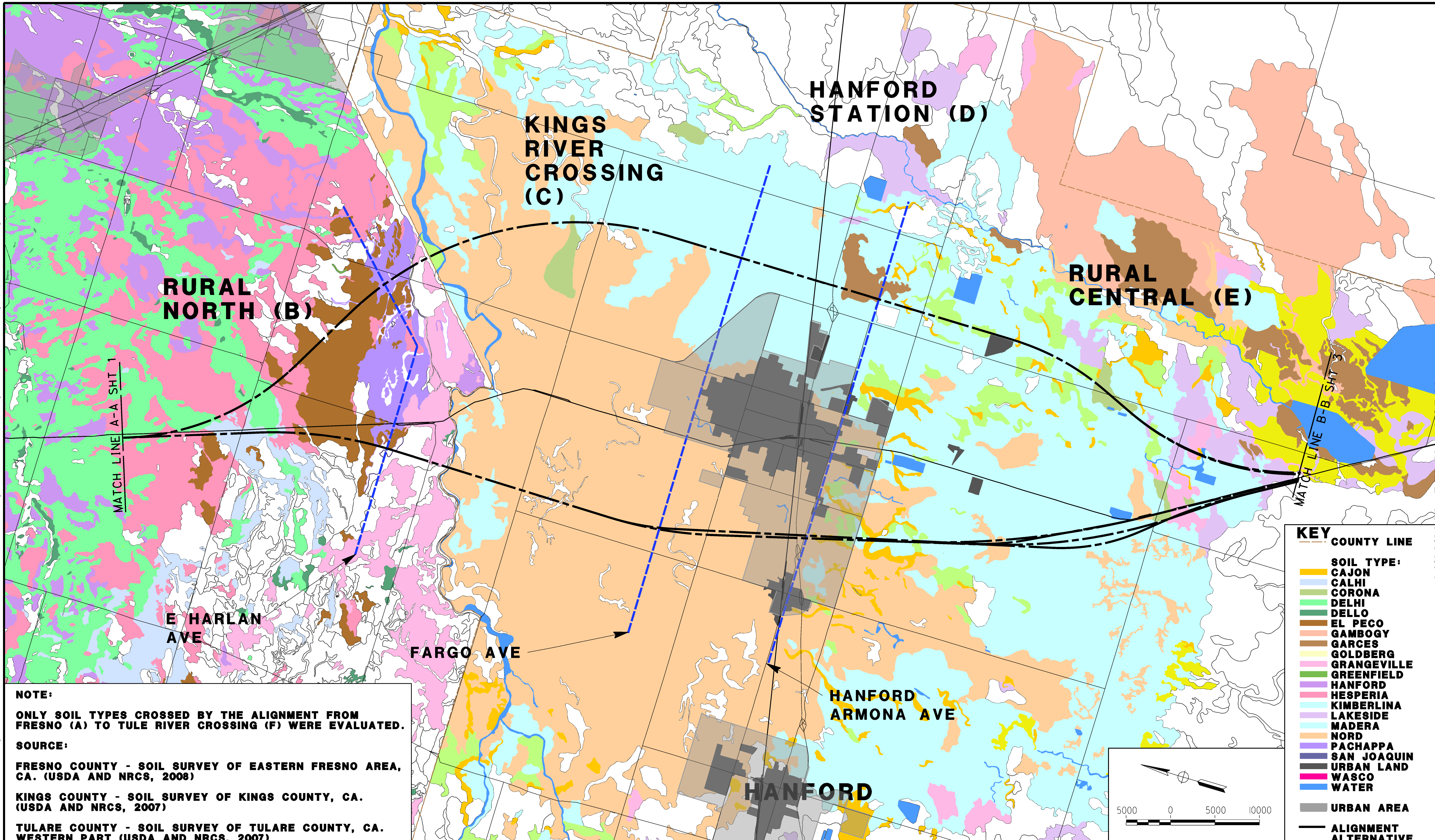

NOTE:

ONLY SOIL TYPES CROSSED BY THE ALIGNMENT FROM FRESNO (A) TO TULE RIVER CROSSING (F) WERE EVALUATED.

SOURCE:

FRESNO COUNTY - SOIL SURVEY OF EASTERN FRESNO AREA, CA. (USDA AND NRCS, 2008)

KINGS COUNTY - SOIL SURVEY OF KINGS COUNTY, CA. (USDA AND NRCS, 2007)

TULARE COUNTY - SOIL SURVEY OF TULARE COUNTY, CA. WESTERN PART (USDA AND NRCS, 2007)

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
USDA AND NRCS SOIL SURVEY: FB-B to FB-E

FIGURE NO.	A7b
DATE	DECEMBER 2013
SHEET NO.	2 of 3

04/02/2014 - RFP No.: HSR13-57

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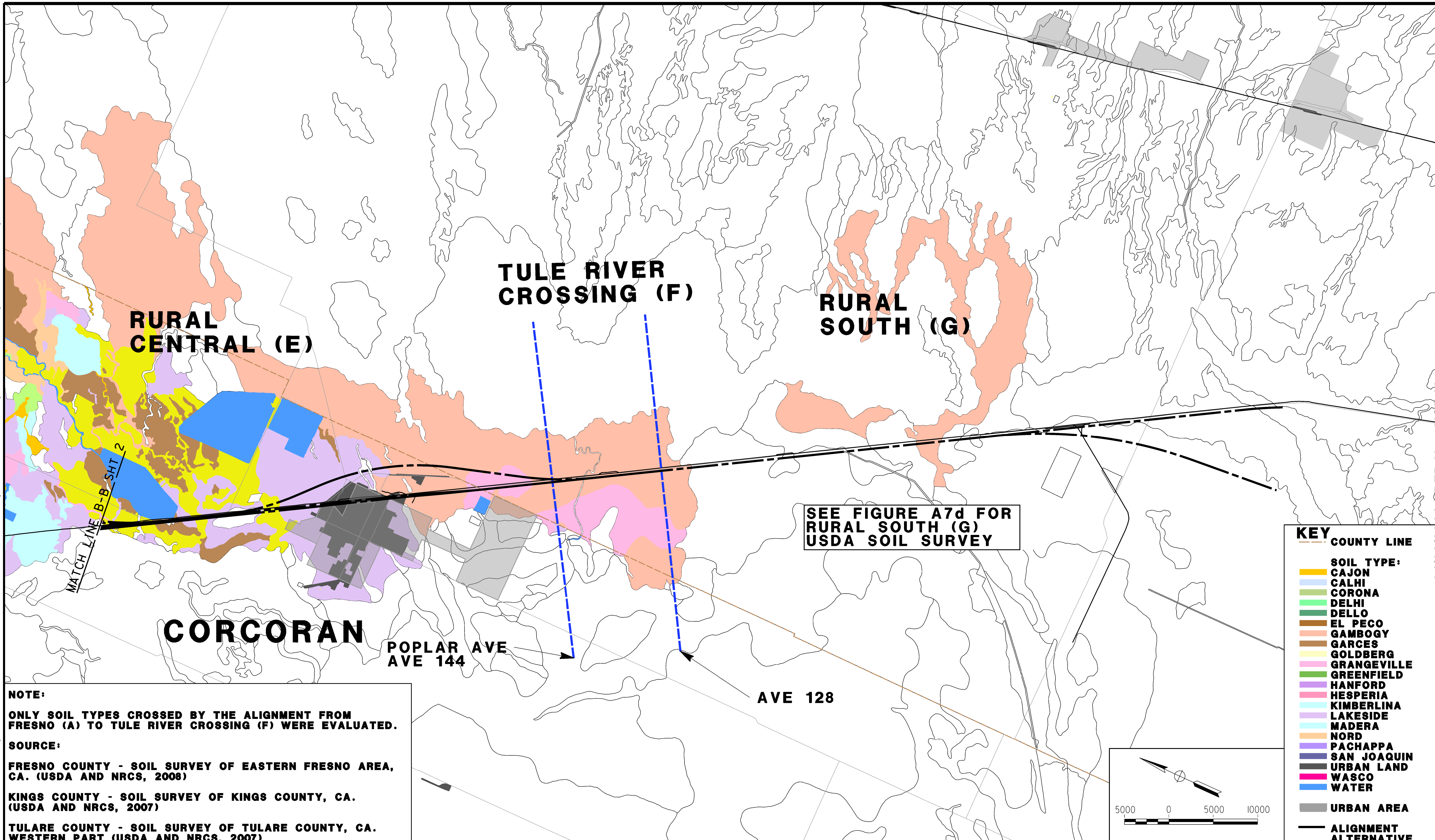

NOTE:

ONLY SOIL TYPES CROSSED BY THE ALIGNMENT FROM FRESNO (A) TO TULE RIVER CROSSING (F) WERE EVALUATED.

SOURCE:

FRESNO COUNTY - SOIL SURVEY OF EASTERN FRESNO AREA, CA. (USDA AND NRCS, 2008)

KINGS COUNTY - SOIL SURVEY OF KINGS COUNTY, CA. (USDA AND NRCS, 2007)

TULARE COUNTY - SOIL SURVEY OF TULARE COUNTY, CA. WESTERN PART (USDA AND NRCS, 2007)

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
USDA AND NRCS SOIL SURVEY: FB-E to FB-G

FIGURE NO.	A7c
DATE	DECEMBER 2013
SHEET NO.	3 of 3

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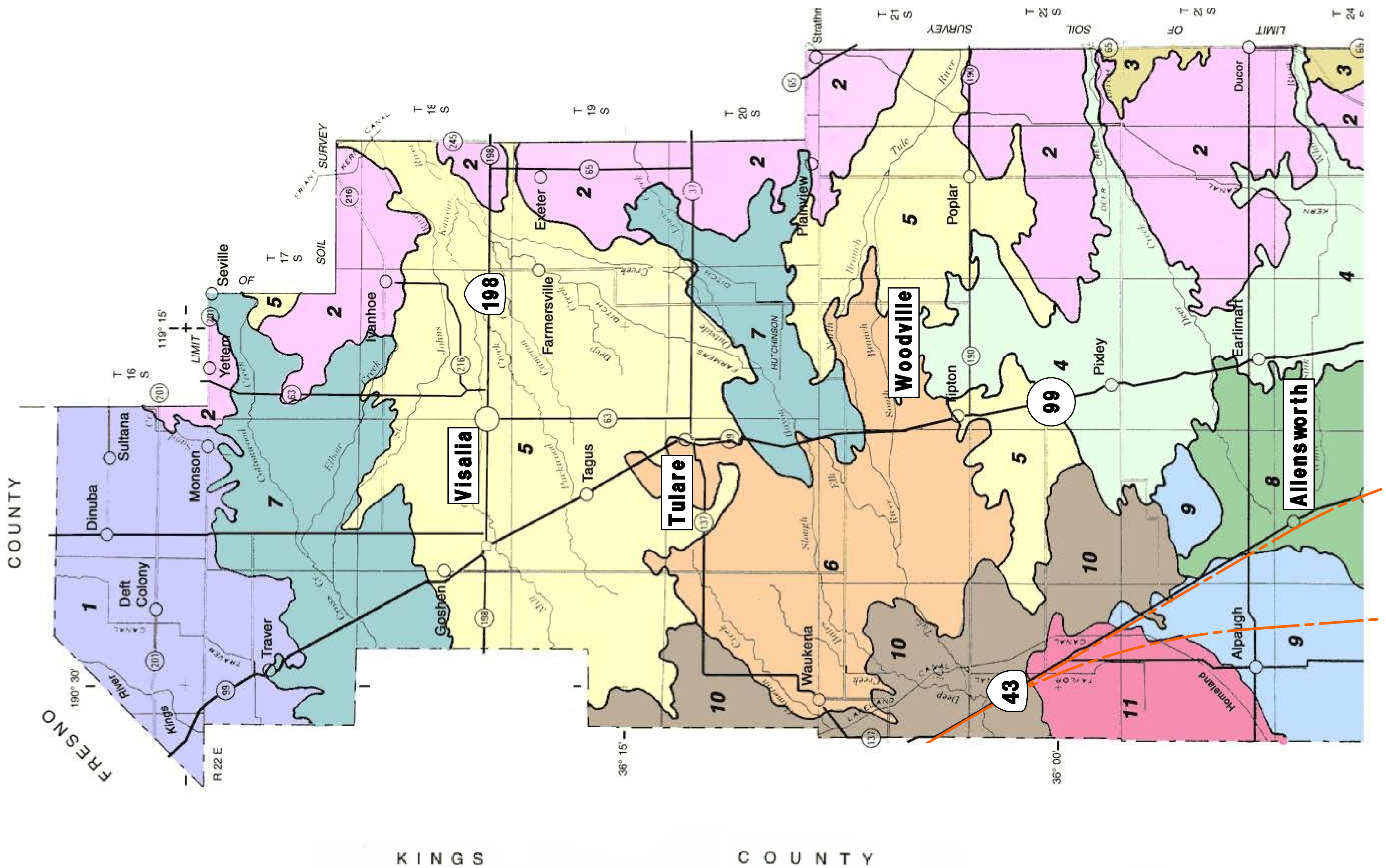
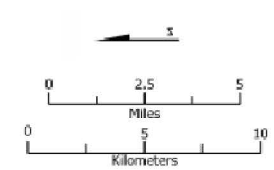




Alternative Proposed HST alignments

8	Gareck-atesh-kimberlina
9	Nahrub-lethent-posochanet
10	Gambogy-biggriz
11	Gepford-houser-armona

Note:

1. Each area outlined on this map consists of more than one kind of soil. The map is thus meant for general planning rather than a basis for decisions on the use of specific tracts.
2. Only soil types crossed by HST alignment are included in legend.

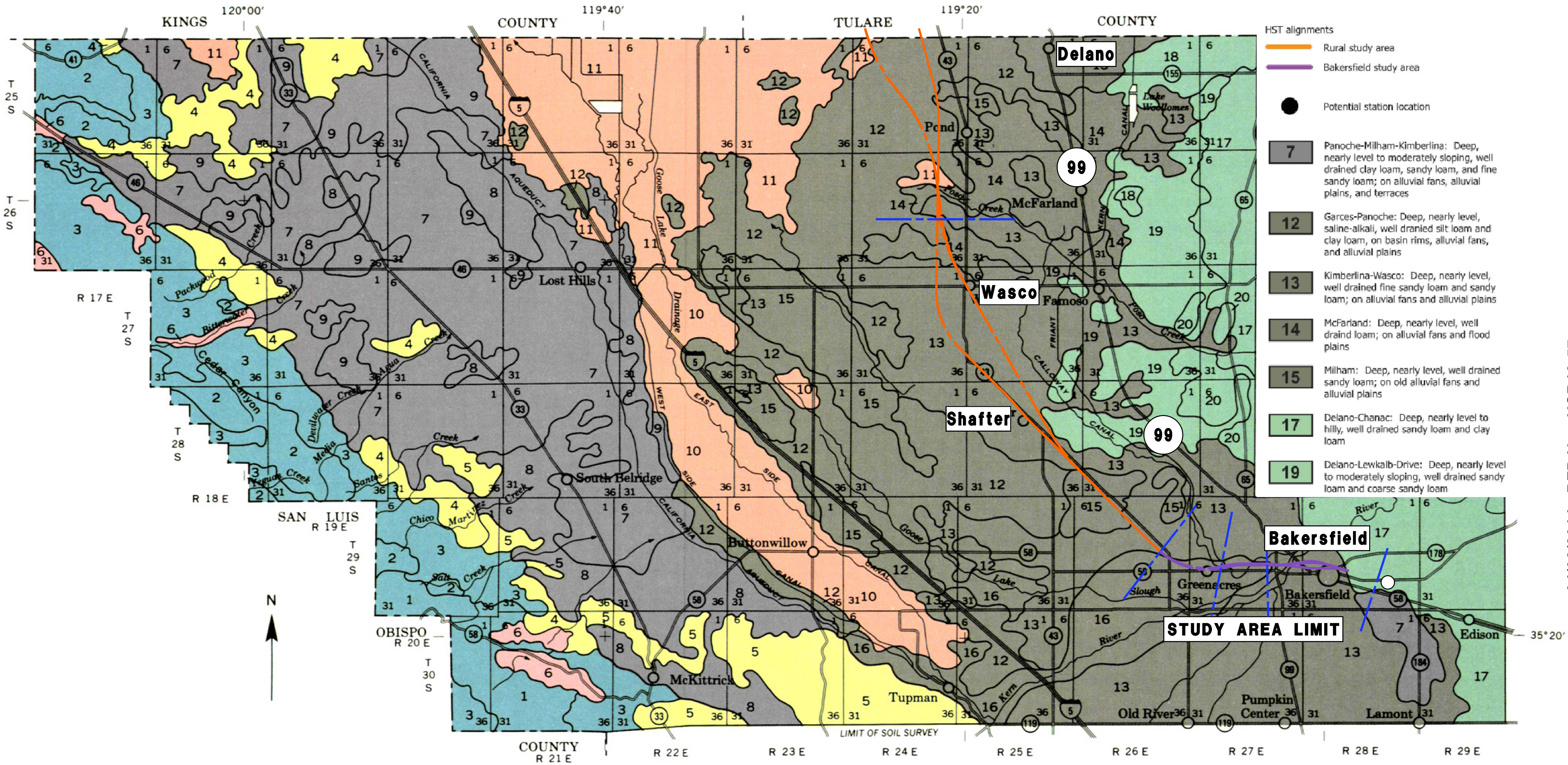
04/02/2014 - RFP No.: HSR13-57

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
USDA AND NRCS SOIL SURVEY: FB-G

FIGURE NO. A7d
DATE DECEMBER 2013
SHEET NO. 1 of 1



Note:

1. Each area outlined on this map consists of more than one kind of soil. The map is thus meant for general planning rather than a basis for decisions on the use of specific tracts.

2. Only soil types crossed by HST alignment are included in legend.

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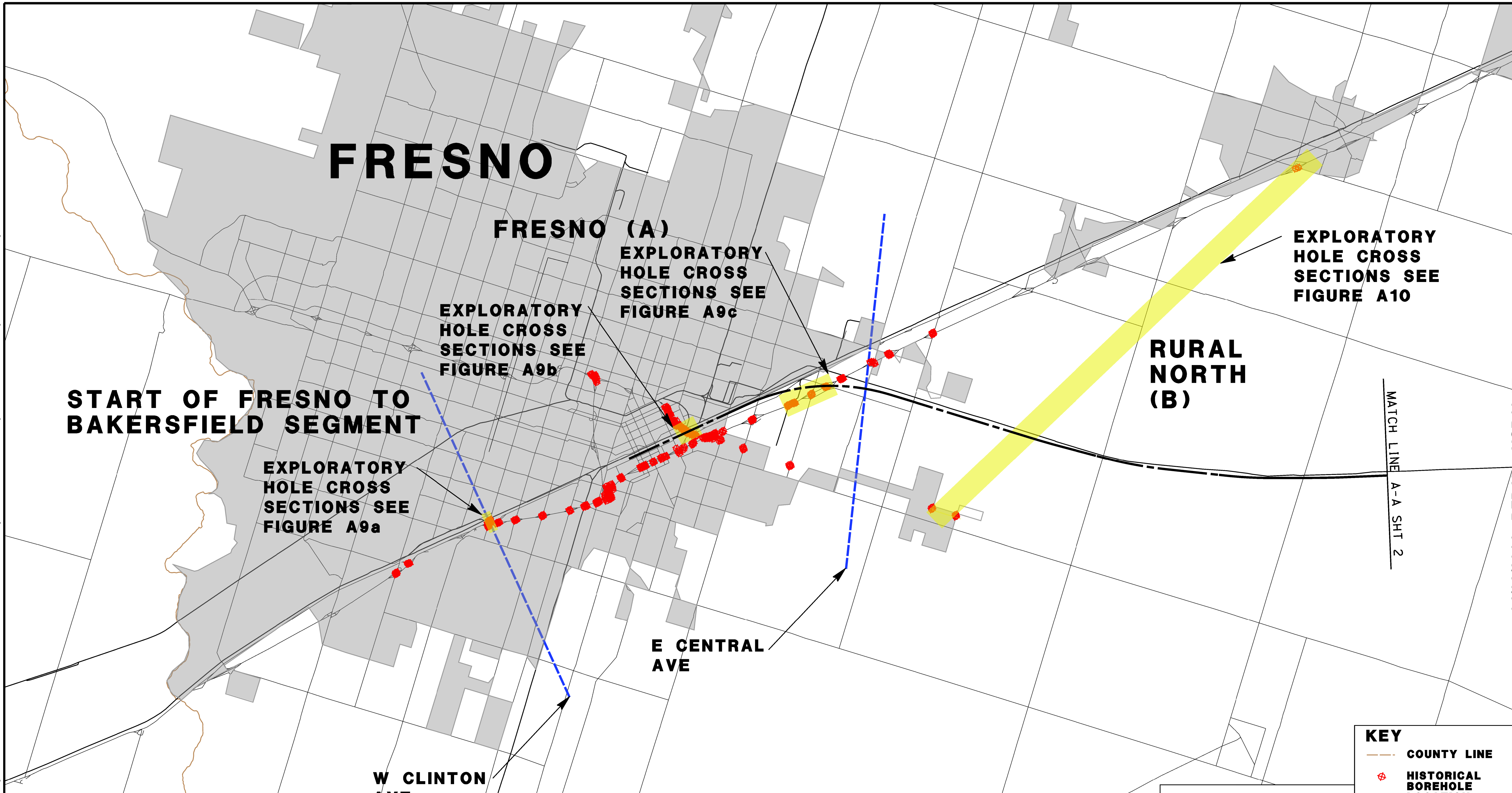
URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
USDA AND NRCS SOIL SURVEY: FB-H TO FB-L

FIGURE NO.	A7e
DATE	DECEMBER 2013
SHEET NO.	1 of 1



SOURCE:

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DETAILS OF SPECIFIC EXPLORATORY HOLES ARE DETAILED IN THE FP GEOTECH HISTORICAL DATA SUMMARY 2010-05-10r1 DOCUMENT AND FP GEOTECHNICAL gINT DATABASE 2010-05-26.

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
HISTORICAL EXPLORATORY HOLE LOCATIONS: FB-A to FB-B

FIGURE NO. A8a
DATE DECEMBER 2013
SHEET NO. 1 of 5

04/02/2014 - RFP No.: HSR13-57

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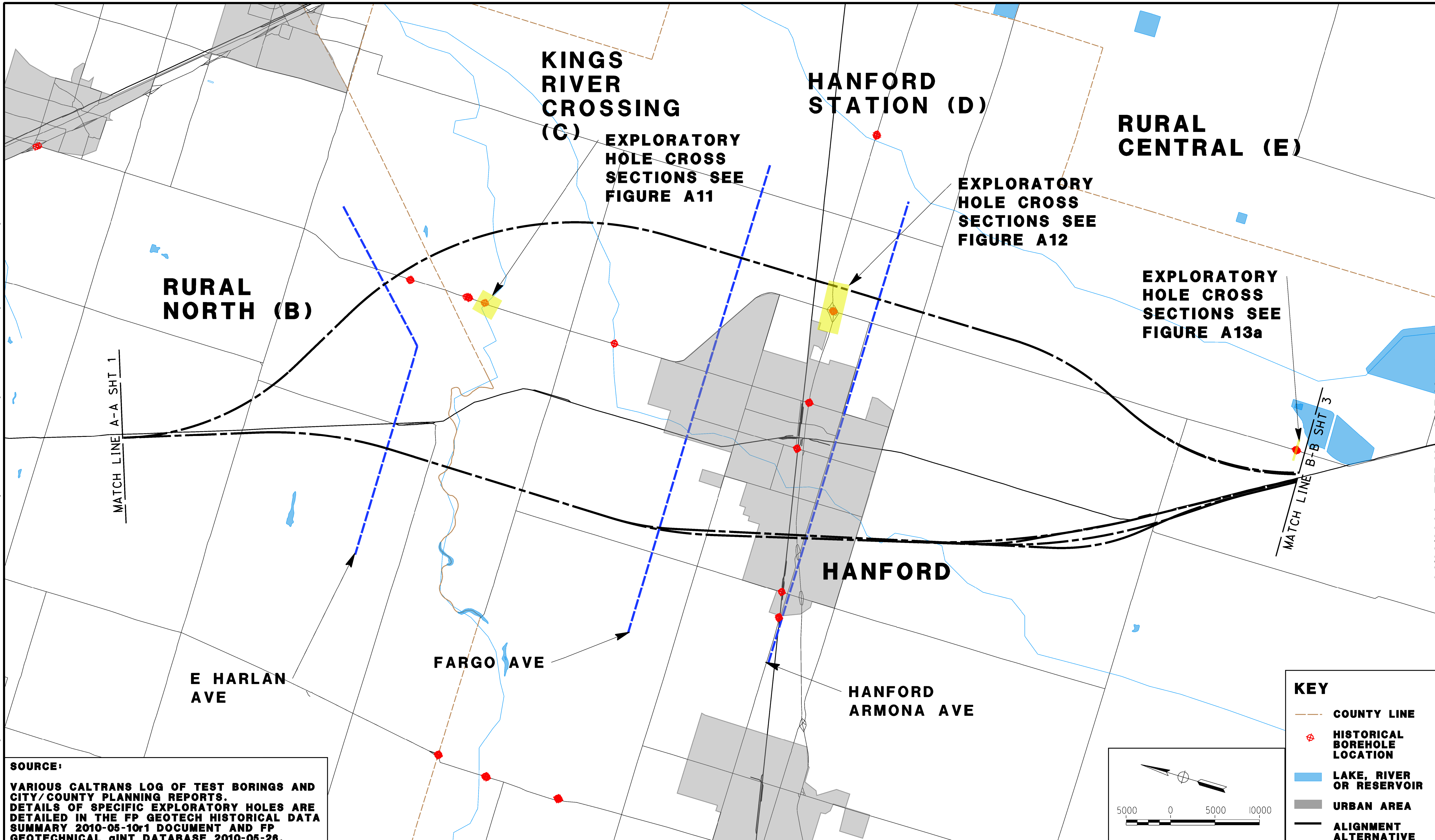

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04/02/2014 - RFP No.: HSR13-57

URS | HMM | ARUP — CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
HISTORICAL EXPLORATORY HOLE LOCATIONS: FB-B to FB-E

FIGURE NO.	A8b
DATE	DECEMBER 2013
SHEET NO.	2 of 5

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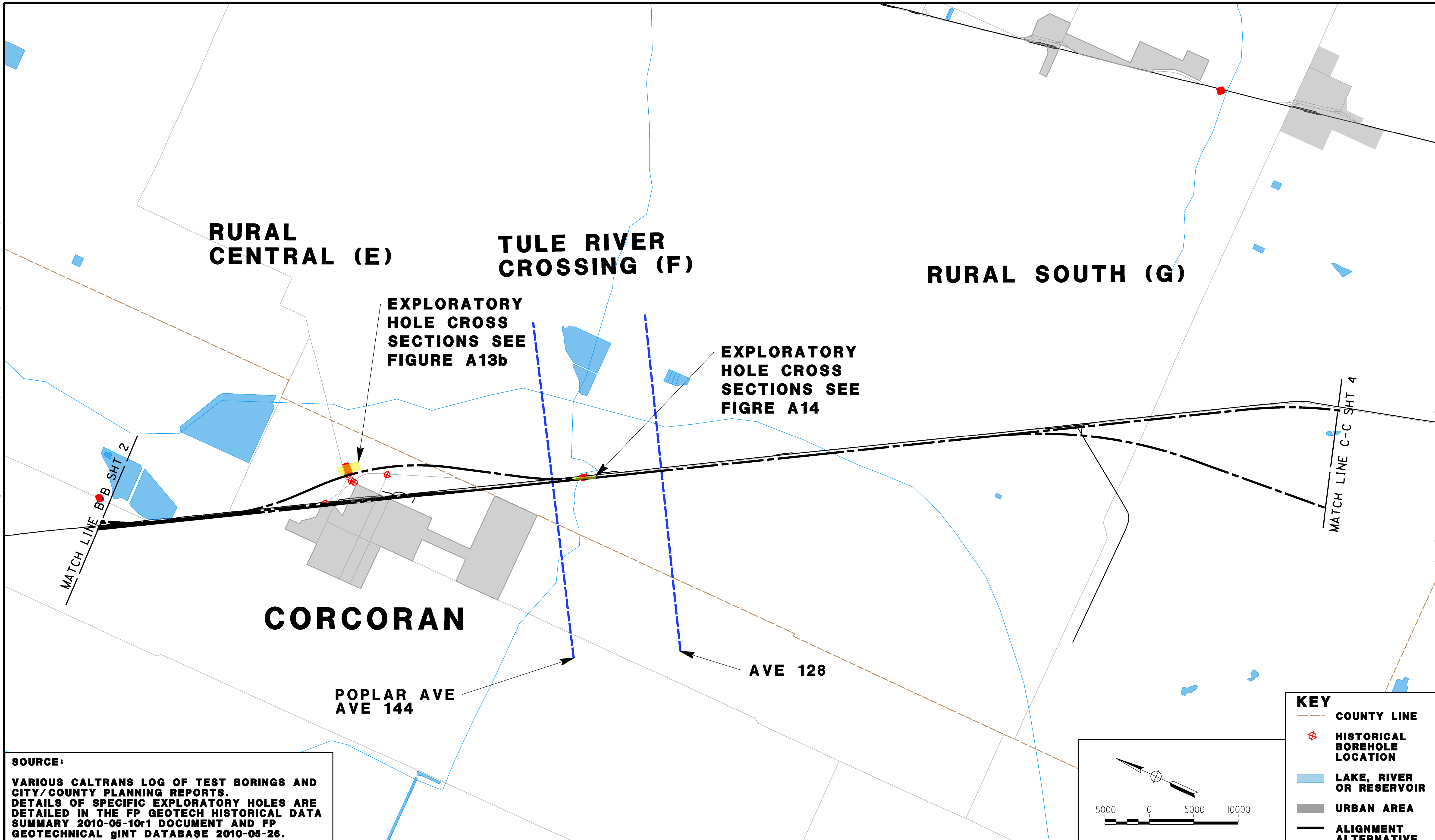

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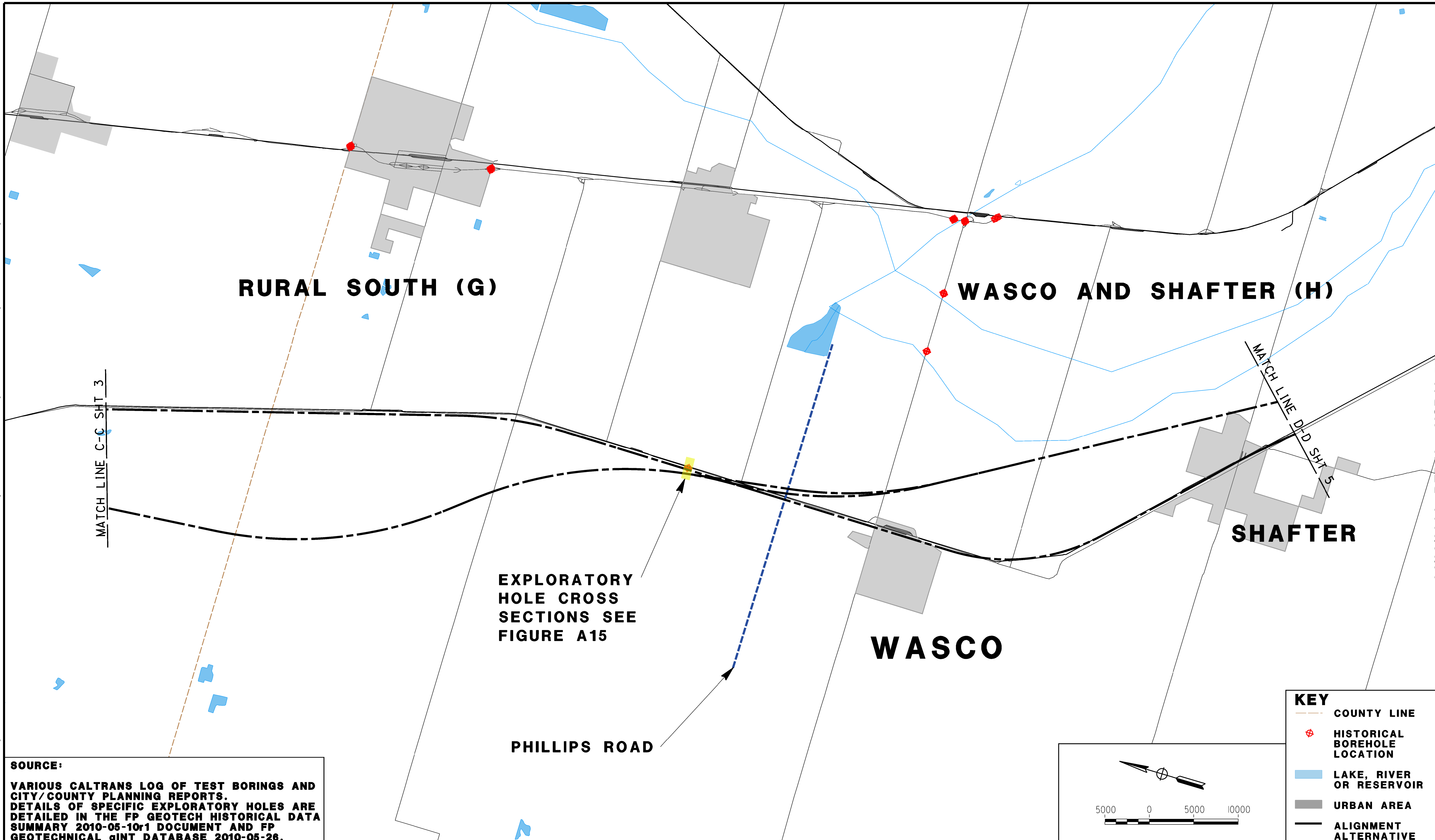
URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
HISTORICAL EXPLORATORY HOLE LOCATIONS: FB-E to FB-G

FIGURE NO. A8c
DATE DECEMBER 2013
SHEET NO. 3 of 5



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DETAILS OF SPECIFIC EXPLORATORY HOLES ARE DETAILED IN THE FP GEOTECH HISTORICAL DATA SUMMARY 2010-05-10r1 DOCUMENT AND FP GEOTECHNICAL gINT DATABASE 2010-05-26.

04/02/2014 - RFP No.: HSR13-57

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
HISTORICAL EXPLORATORY HOLE LOCATIONS: FB-G to FB-H

FIGURE NO.	A8d
DATE	DECEMBER 2013
SHEET NO.	4 of 5

\\global\americas\Jobs\S-F\131000\131577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\2012-01-11_ 15% Seismic & Geologic

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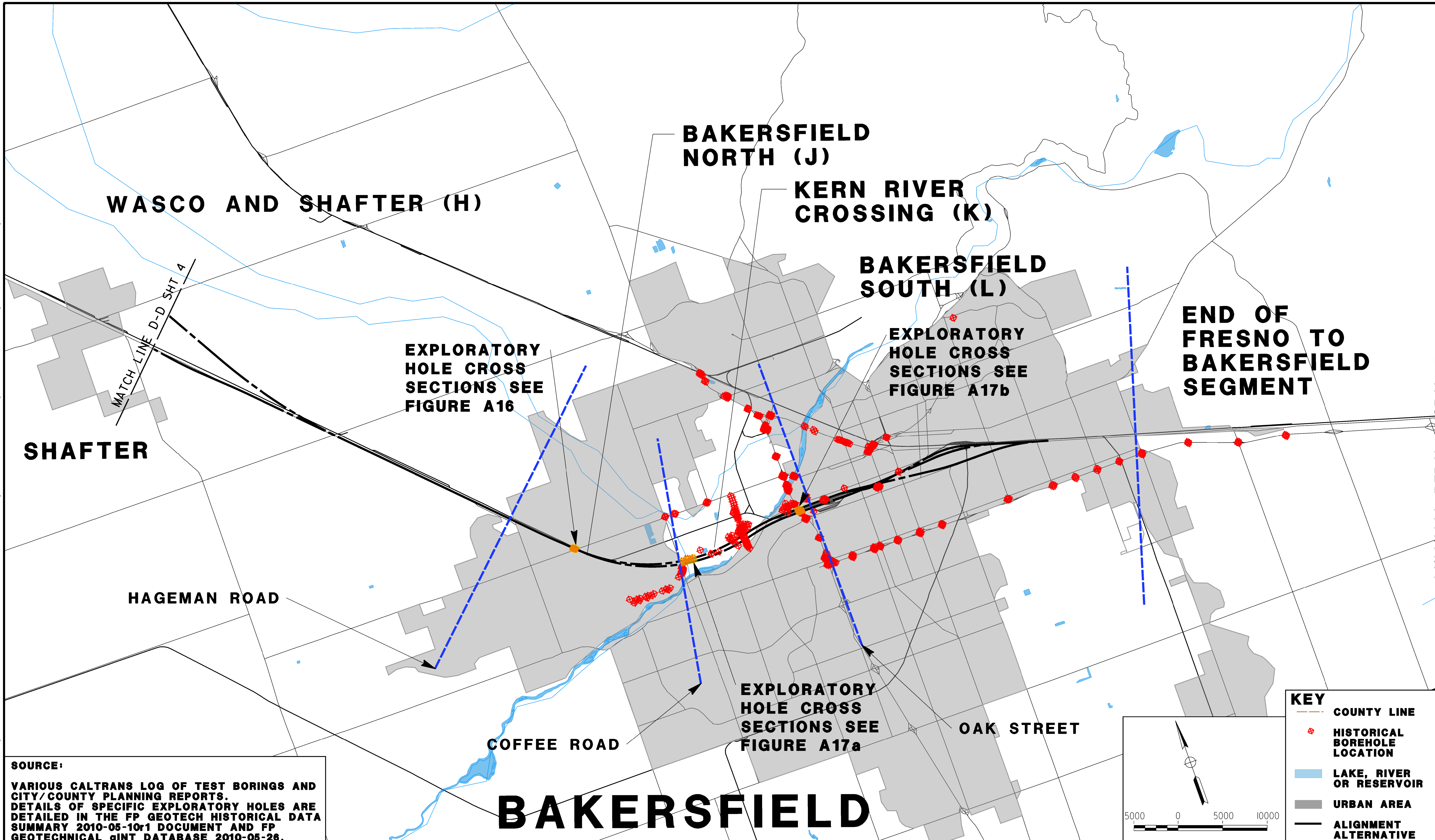


SOURCE:

VARIOUS CALTRANS LOG OF TEST BORINGS AND CITY/COUNTY PLANNING REPORTS.
DETAILS OF SPECIFIC EXPLORATORY HOLES ARE DETAILED IN THE FP GEOTECH HISTORICAL DATA SUMMARY 2010-05-10r1 DOCUMENT AND FP GEOTECHNICAL gINT DATABASE 2010-05-26.

URS | HMM | ARUP — CALIFORNIA HIGH-SPEED TRAIN

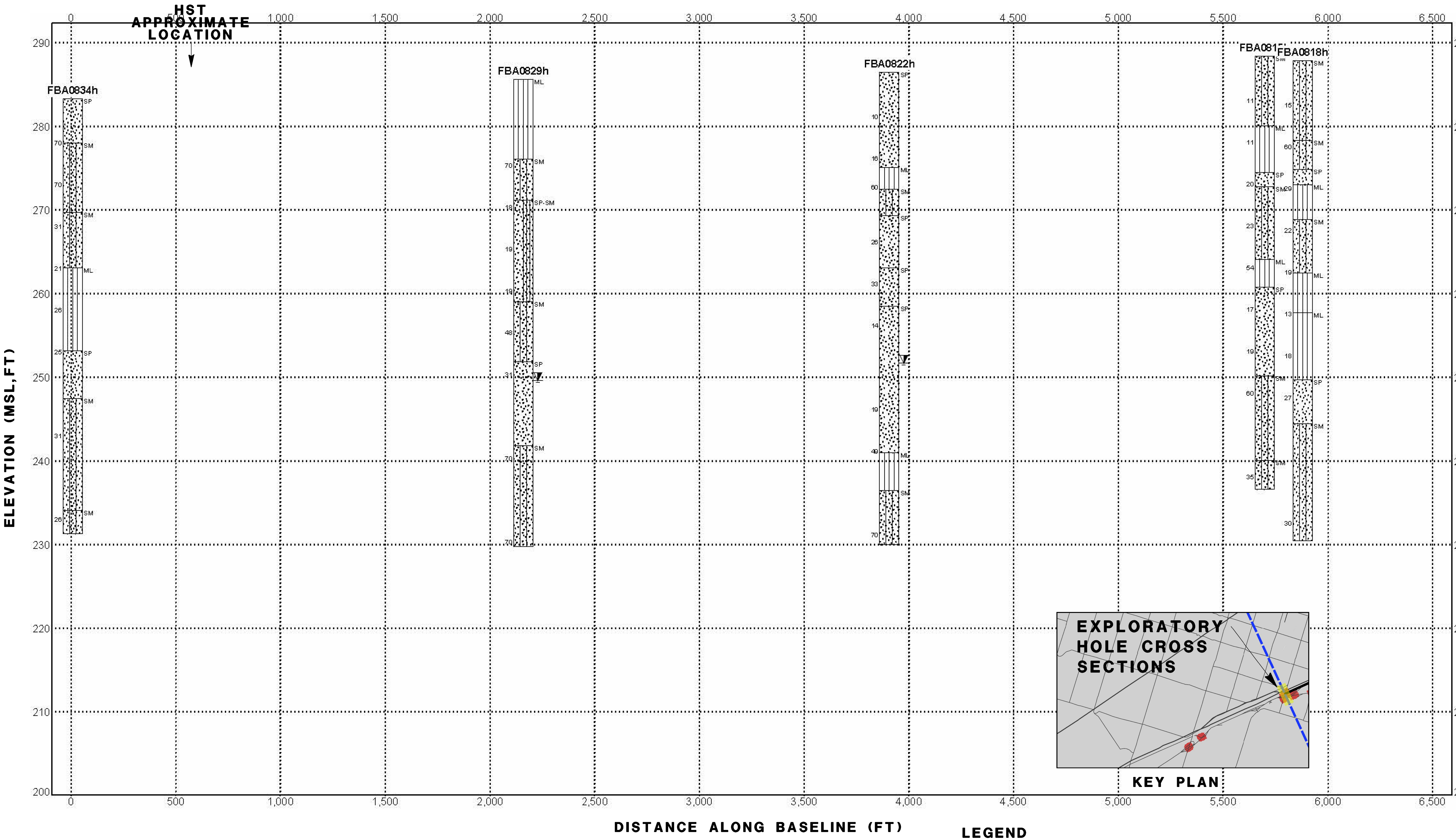
CALIFORNIA HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
HISTORICAL EXPLORATORY HOLE LOCATIONS: FB-H to FB-L

FIGURE NO. A8e
DATE DECEMBER 2013
SHEET NO. 5 of 5

Jodi.Borghesi 12/16/2013 9:21:04 AM \\global\americas\Jobs\S-F\131000\131577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\2012-01-11_ 15% Seismic & Geologic

04/02/2014 - RFP No.: HSR13-57



LEGEND

Silty Sand (SM)
Silt (ML)
Poorly-graded Sand (SP)
Poorly-graded Sand with Silt (SP-SM)

SPT N VALUE → 71

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
STRATIGRAPHY: FRESNO (FB-A)
I-99/WEST CLINTON AVENUE

FIGURE NO.	A9a
DATE	DECEMBER 2013
SHEET NO.	1 of 3

Jodi.Borghesi 12/16/2013 10:08:43 AM \\global\americas\Jobs\S-F\131000\131577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\2012-01-11_ 15% Seismic & Geologic

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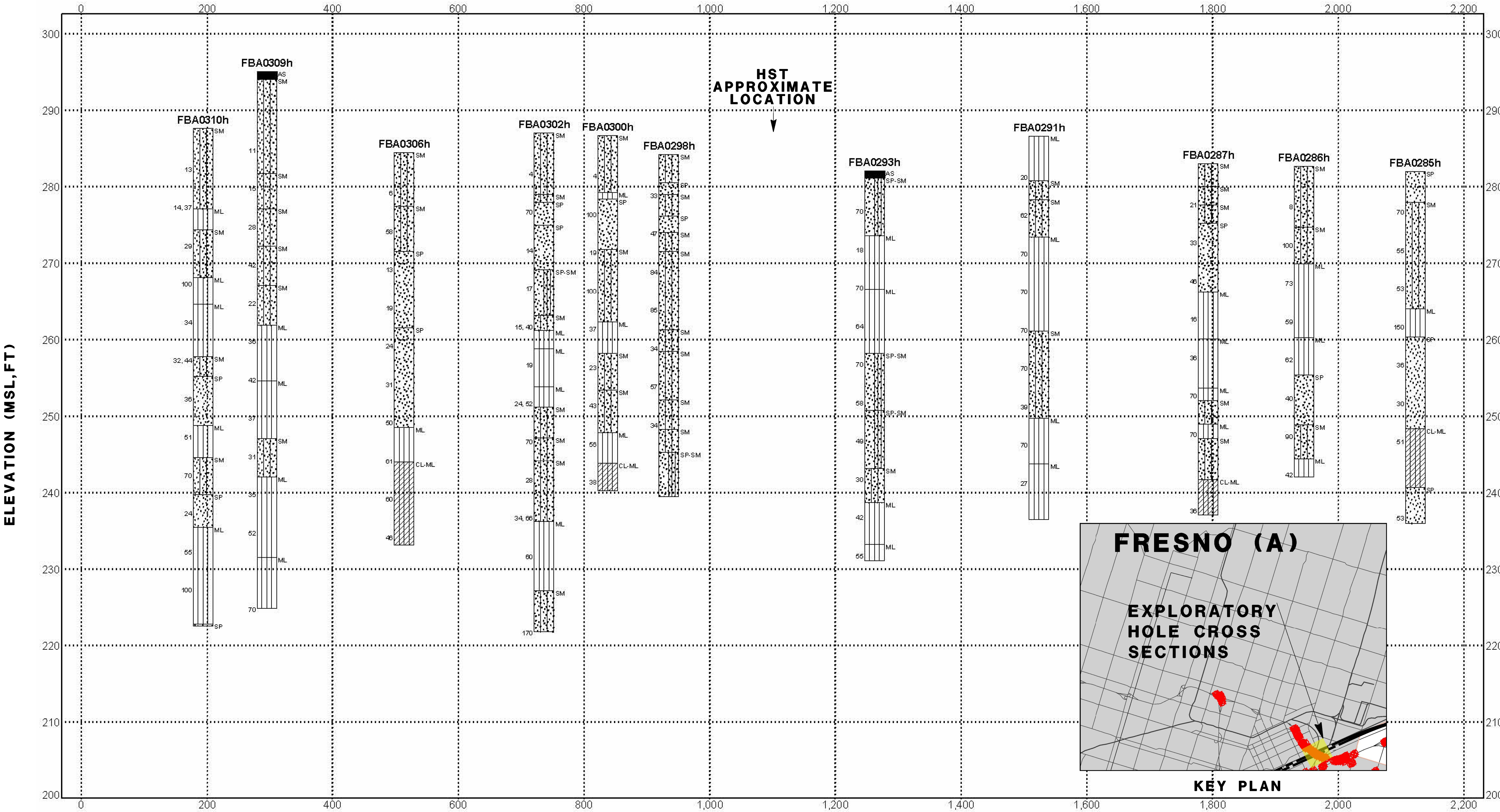


KEY PLAN

LEGEND

- Poorly-graded Sand (SP)
- Silty Sand (SM)
- Silt (ML)
- Low Plasticity Silty Clay (CL-ML)
- Asphalt (AS)
- Poorly-graded Sand with Silt (SP-SM)

SPT N VALUE → 71

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

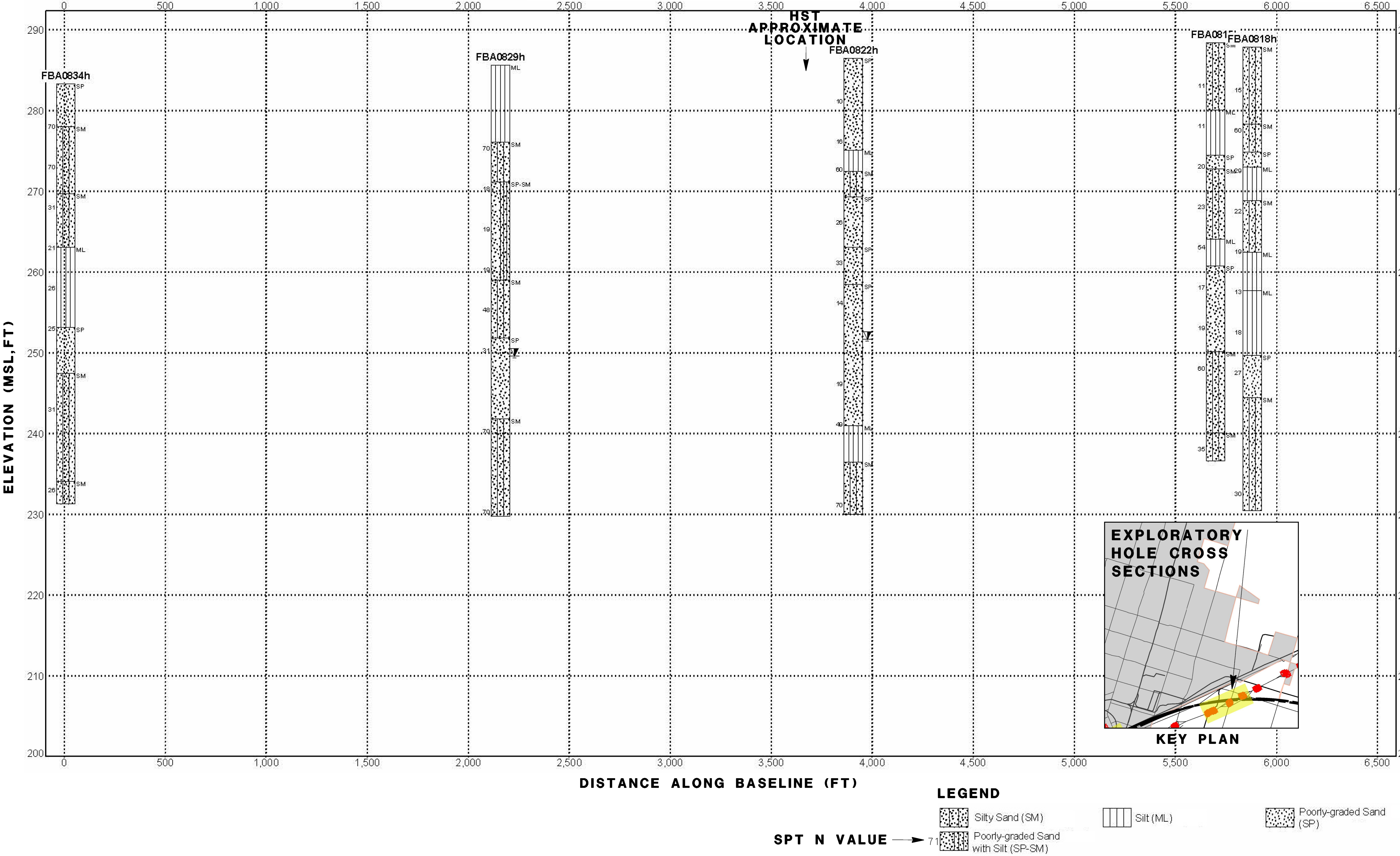
CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
STRATIGRAPHY: FRESNO (FB-A)
HIGHWAY 41 CROSSING

FIGURE NO.	A9b
DATE	DECEMBER 2013
SHEET NO.	2 of 3

04/02/2014 - RFP No.: HSR13-57

Jodi.Borghesi 12/16/2013 10:10:13 AM \\global\americas\Jobs\S-F\131000\131577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\2012-01-11_ 15% Seismic & Geologic



04/02/2014 - RFP No.: HSR13-57

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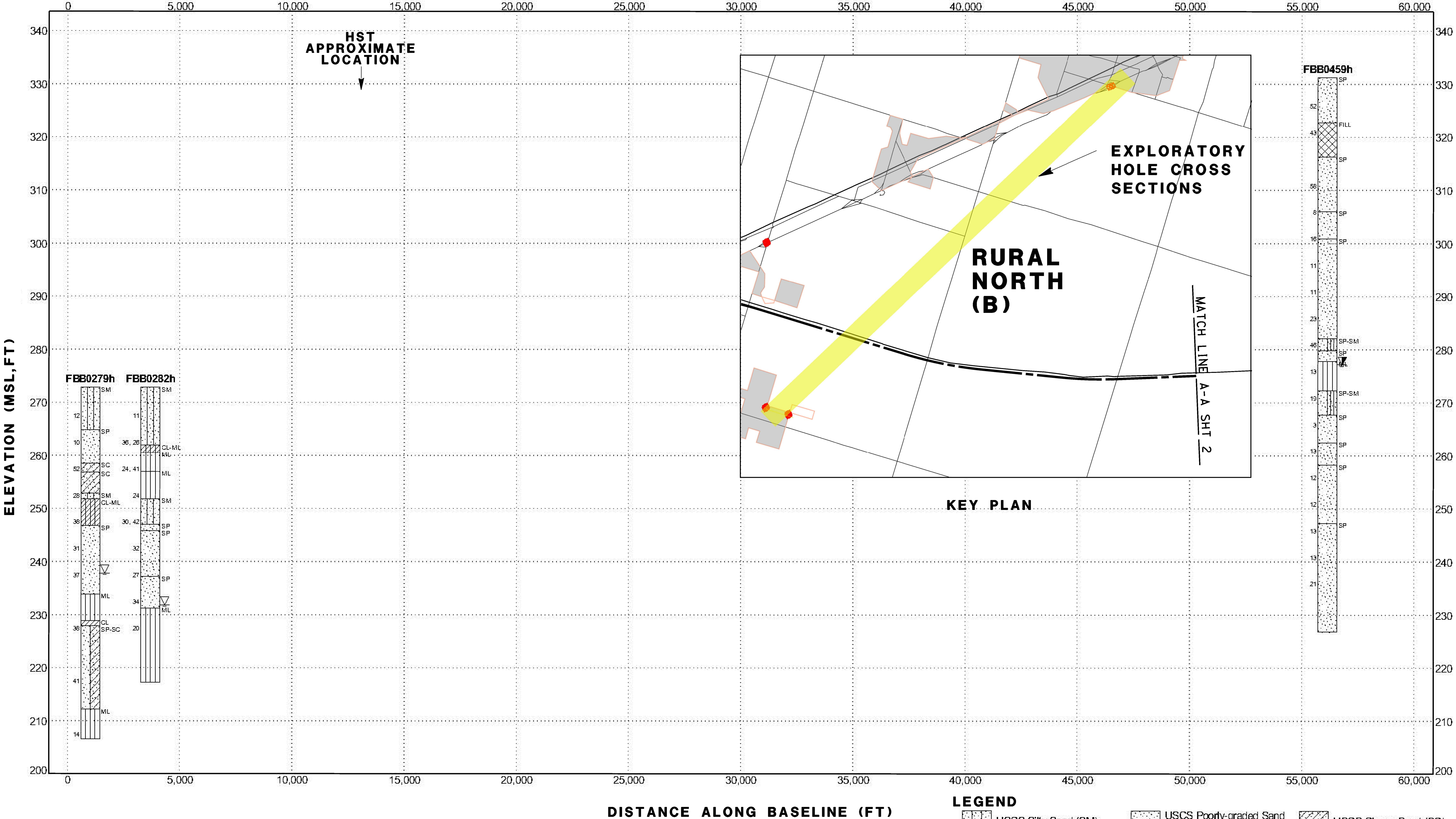
URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
STRATIGRAPHY: FRESNO (FB-A)
I-99 AND E. NORTH AVE

FIGURE NO.	A9c
DATE	DECEMBER 2013
SHEET NO.	3 of 3



LEGEND

- USCS Silty Sand (SM)
- USCS Poorly-graded Sand (SP)
- USCS Clayey Sand (SC)
- USCS Low Plasticity Silty Clay (CL-ML)
- USCS Silt (ML)
- USCS Low Plasticity Clay (CL)
- USCS Poorly-graded Sand with Clay (SP-SC)
- Fill (made ground) (FILL)
- USCS Poorly-graded Sand with Silt (SP-SM)

SPT N VALUE → 71

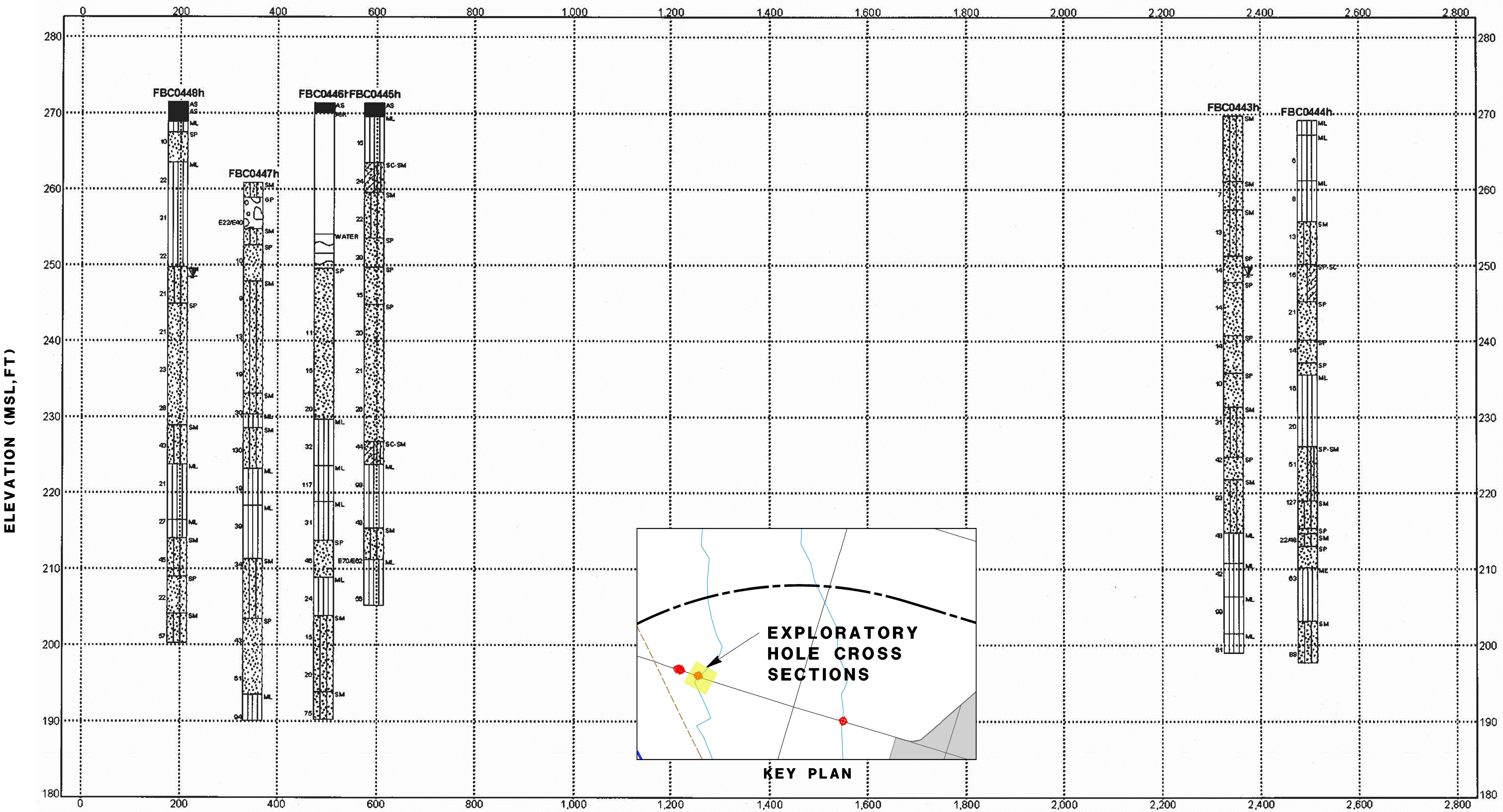
04/02/2014 - RFP No.: HSR13-57

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
STRATIGRAPHY: RURAL NORTH (FB-B)

FIGURE NO.	A10
DATE	DECEMBER 2013
SHEET NO.	1 of 1



LEGEND

- Silty Sand (SM)
- Poorly-graded Sand with Clay (SP-SC)
- Clayey Sand (SC-SM)
- Poorly-graded Gravel (GP)
- Poorly-graded Sand (SP)
- Poorly-graded Sand with Silt (SP-SM)
- Air (Air)
- Silt (ML)
- Asphalt (AS)
- Water (Water)

SPT N VALUE → 71

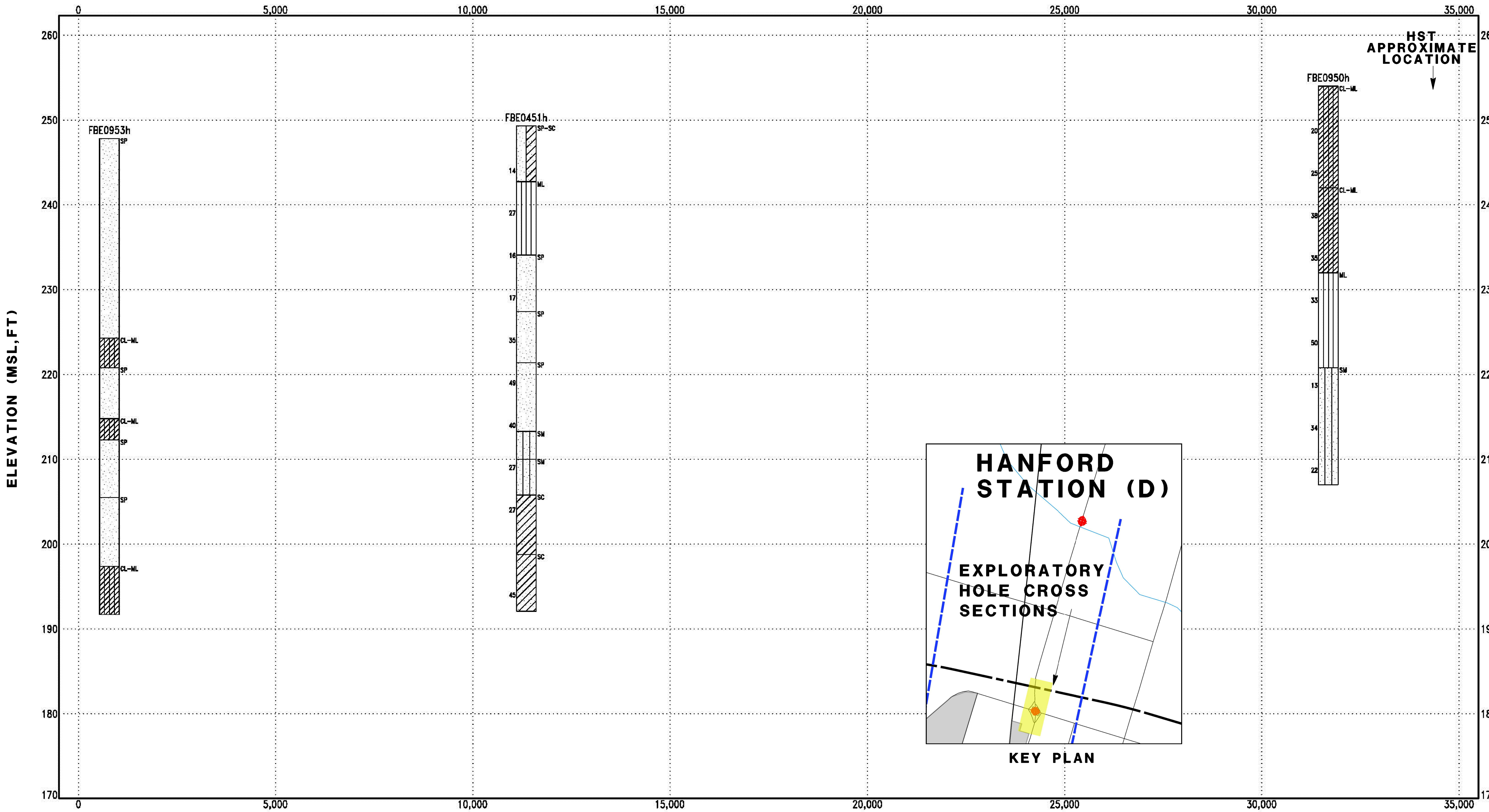
URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
STRATIGRAPHY: KINGS RIVER CROSSING (FB-C)

FIGURE NO.	A11
DATE	DECEMBER 2013
SHEET NO.	1 of 1

Jodi.Borghesi 12/16/2013 10:37:13 AM \\global\americas\Jobs\S-F\131000\131577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\2012-01-11_ 15% Seismic & Geologic



DISTANCE ALONG BASELINE (FT)

SPT N VALUE → 71

LEGEND

- Poorly-graded Sand with Clay (SP-SC)
- Silty Sand (SM)
- Silt (ML)
- Clayey Sand (SC)
- Poorly-graded Sand (SP)
- Low Plasticity Silty Clay (CL-ML)

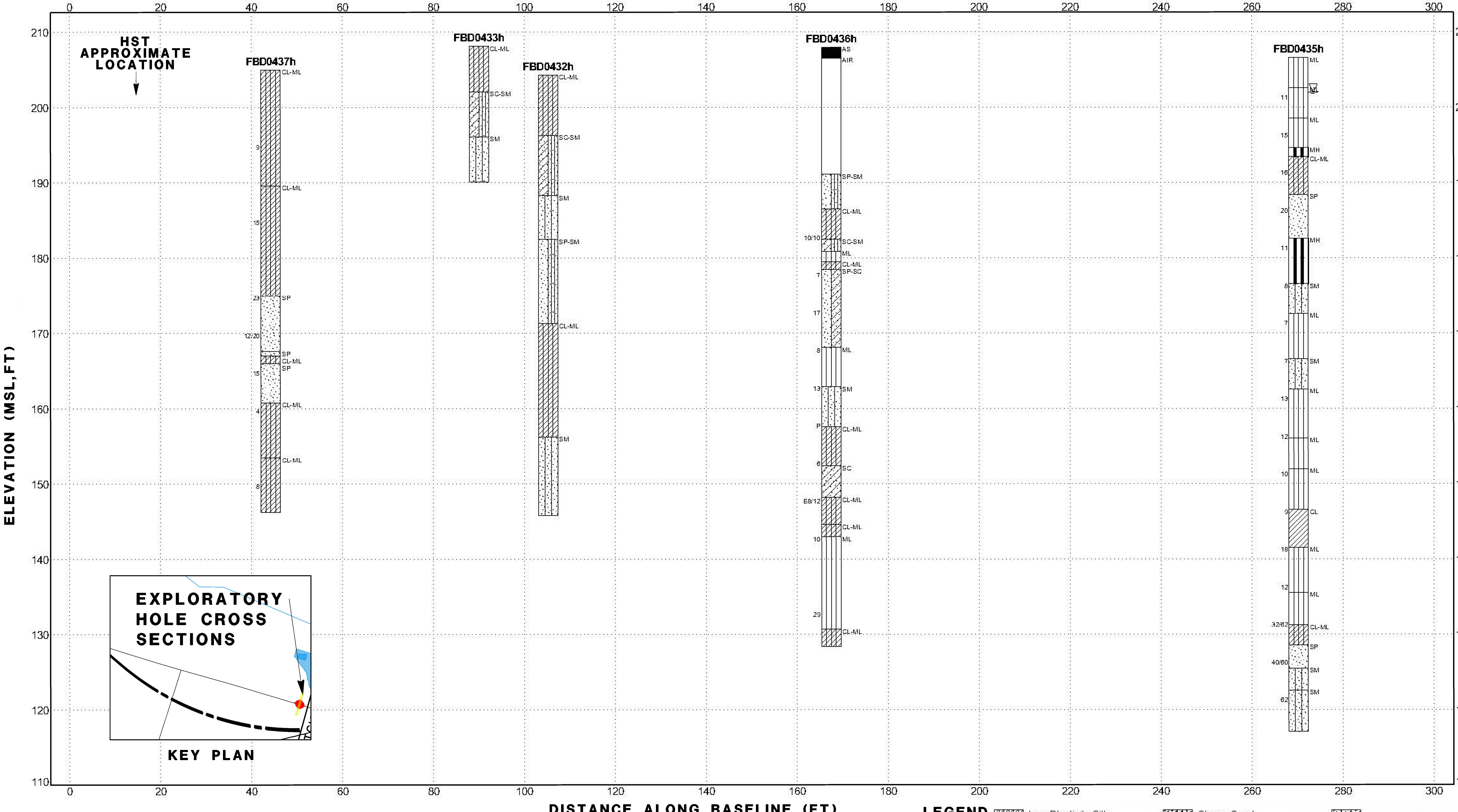
04/02/2014 - RFP No.: HSR13-57

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
STRATIGRAPHY: HANFORD STATION (FB-D)

FIGURE NO.	A12
DATE	DECEMBER 2013
SHEET NO.	1 of 1



LEGEND

Low Plasticity Silty Clay (CL-ML)	Clayey Sand (SC-SM)	Silty Sand (SM)
Poorly-graded Sand with Silt (SP-SM)	Silt (ML)	Elastic Silt (MH)
Poorly-graded Sand (SP)	Low Plasticity Clay (CL)	Asphalt (AS)
Air (Air)	Poorly-graded Sand with Clay (SP-SC)	Clayey Sand (SC)

SPT N VALUE → 71

04/02/2014 - RFP No.: HSR13-57

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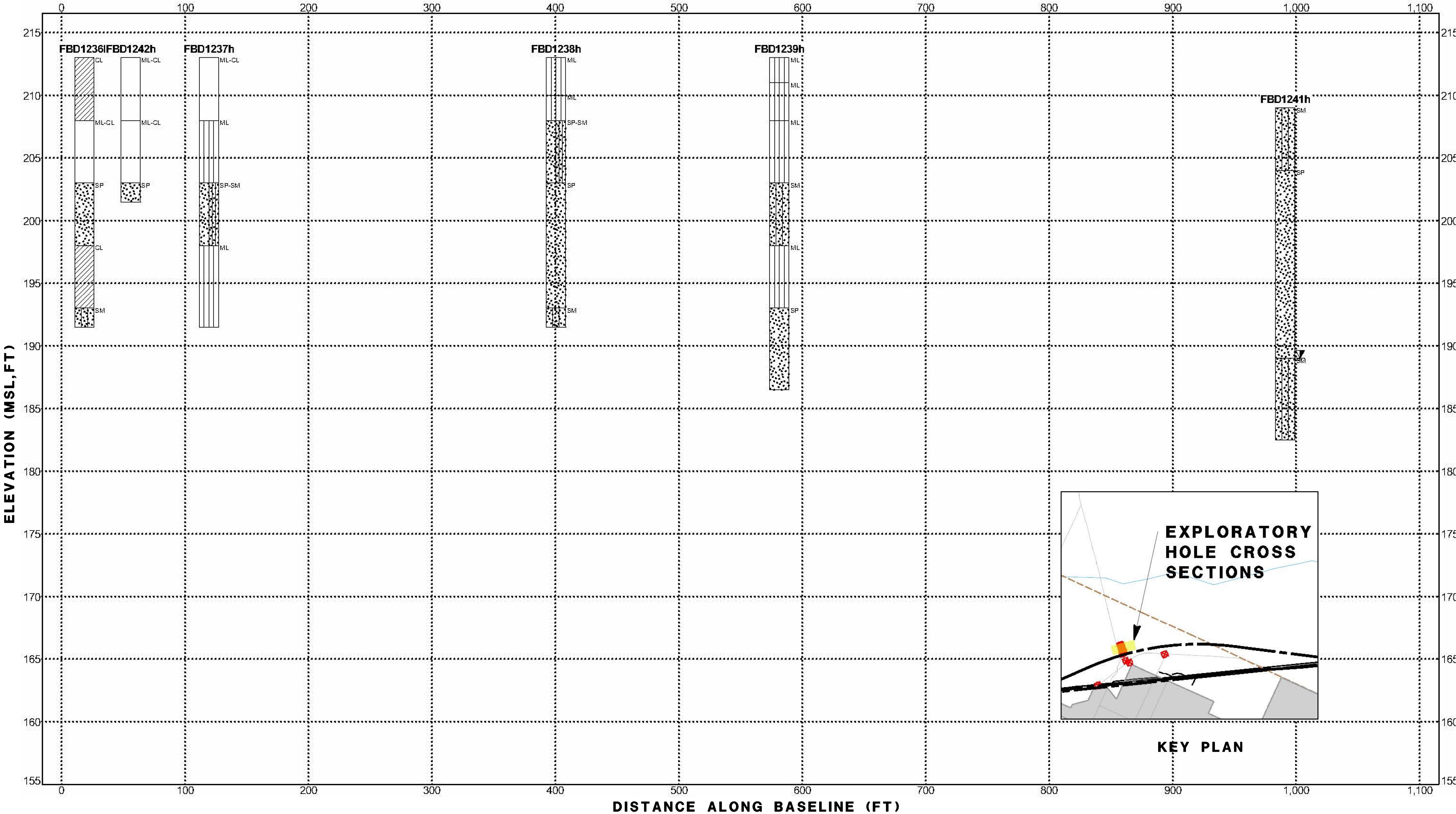
URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
STRATIGRAPHY: RURAL CENTRAL (FB-E)
(6 MILES NORTH OF CORCORAN)

FIGURE NO.	A13a
DATE	DECEMBER 2013
SHEET NO.	1 of 2



LEGEND

SPT N VALUE → 71

Low Plasticity Clay (CL)	(ML-CL)	Poorly-graded Sand (SP)
Silty Sand (SM)	Silt (ML)	Poorly-graded Sand with Silt (SP-SM)

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

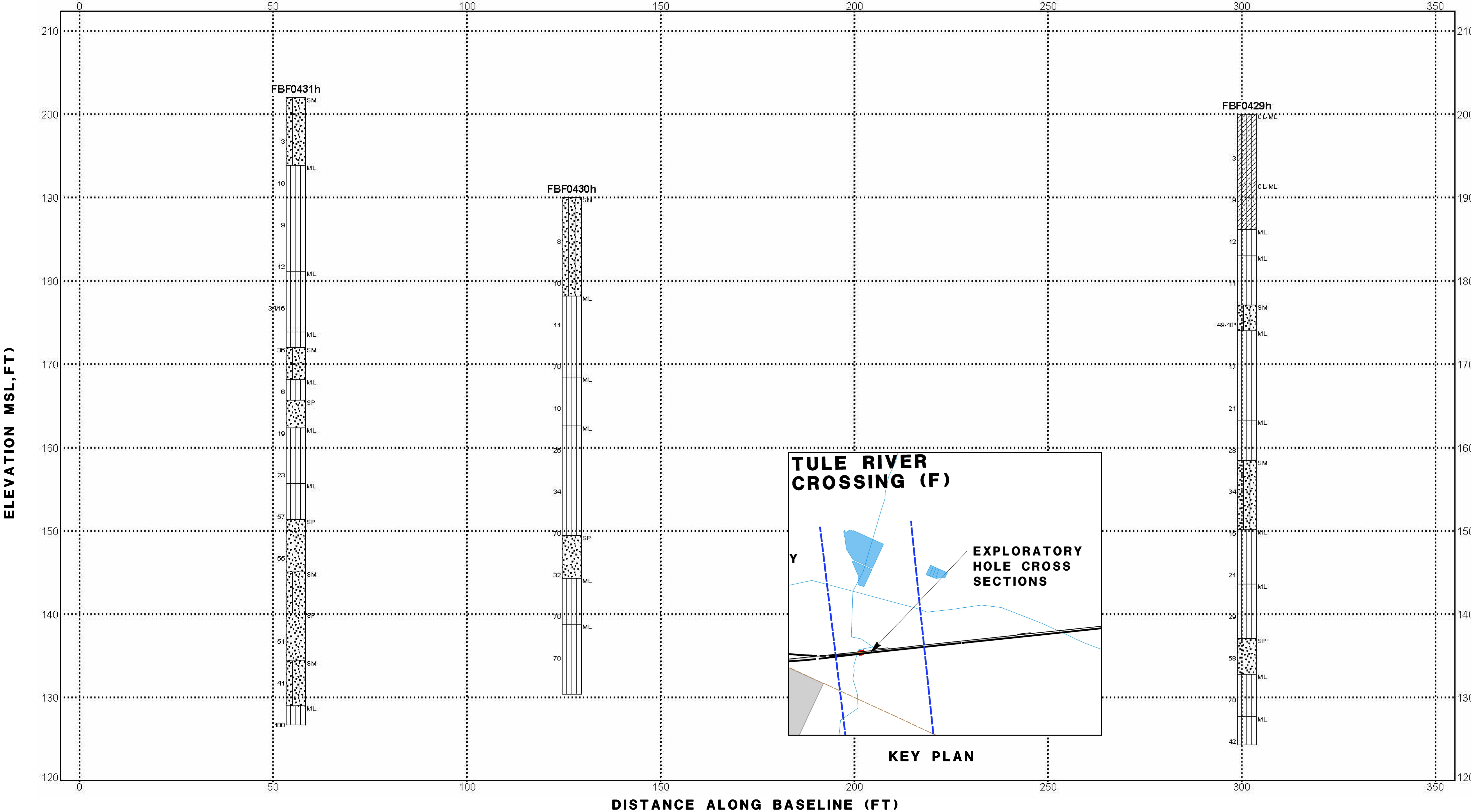
CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
STRATIGRAPHY: RURAL CENTRAL (FB-E)

FIGURE NO. A13b
DATE DECEMBER 2013
SHEET NO. 2 of 2

04/02/2014 - RFP No.: HSR13-57

Jodi.Borghesi 12/16/2013 10:39:16 AM \\global\americas\Jobs\S-F\131000\131577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\2012-01-11_ 15% Seismic & Geologic



LEGEND

Low Plasticity Silty Clay (CL-ML)

Silt (ML)

Silty Sand (SM)

SPT N VALUE → 71

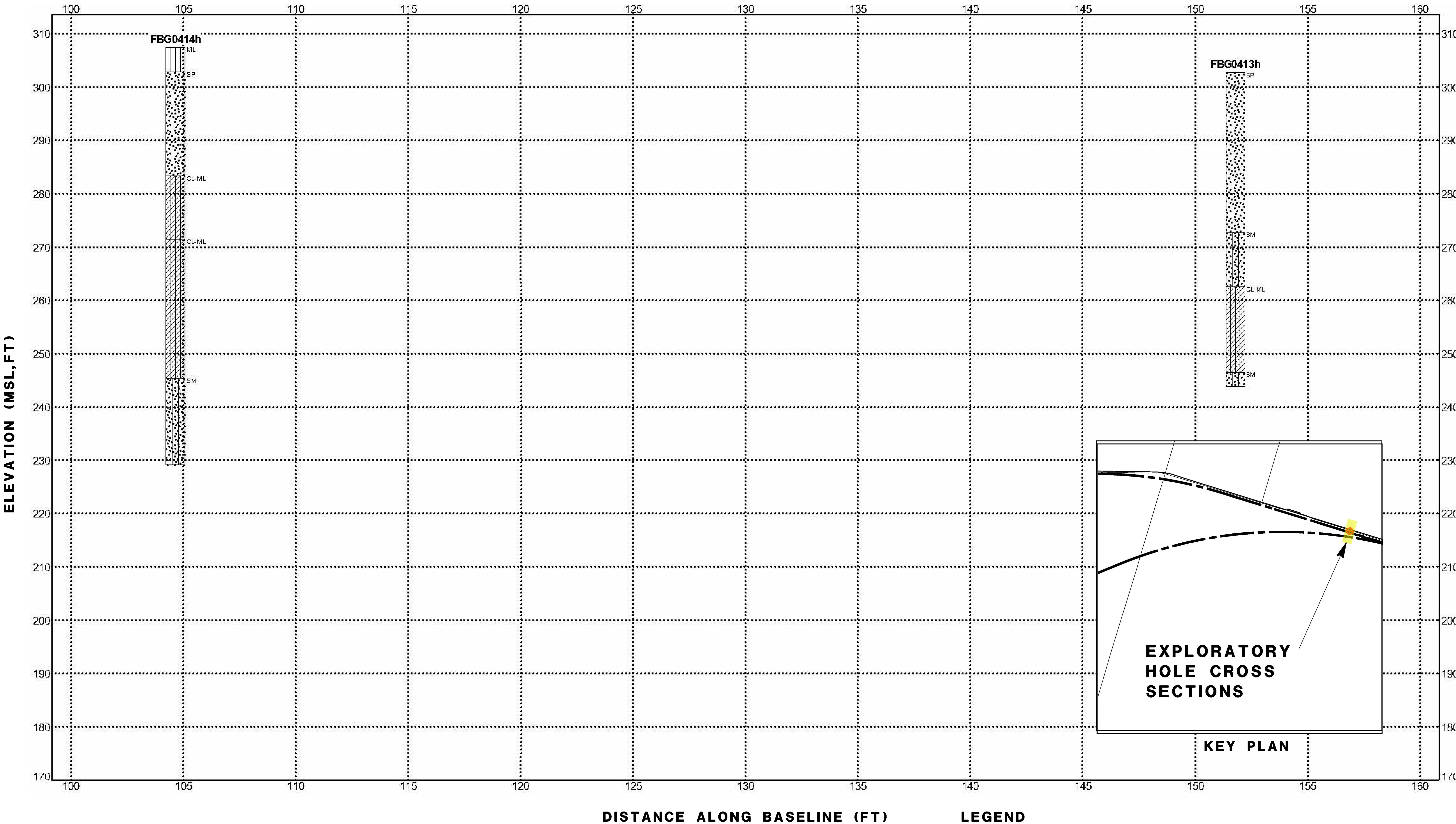
Poorly-graded Sand (SP)

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
STRATIGRAPHY: TULE RIVER CROSSING (FB-F)

FIGURE NO.	A14
DATE	DECEMBER 2013
SHEET NO.	1 of 1



LEGEND

Poorly-graded Sand (SP)
Silt (ML)
Silty Sand (SM)
Well-graded Sand (SW)
Low Plasticity Silty Clay (CL-ML)

SPT N VALUE → 71

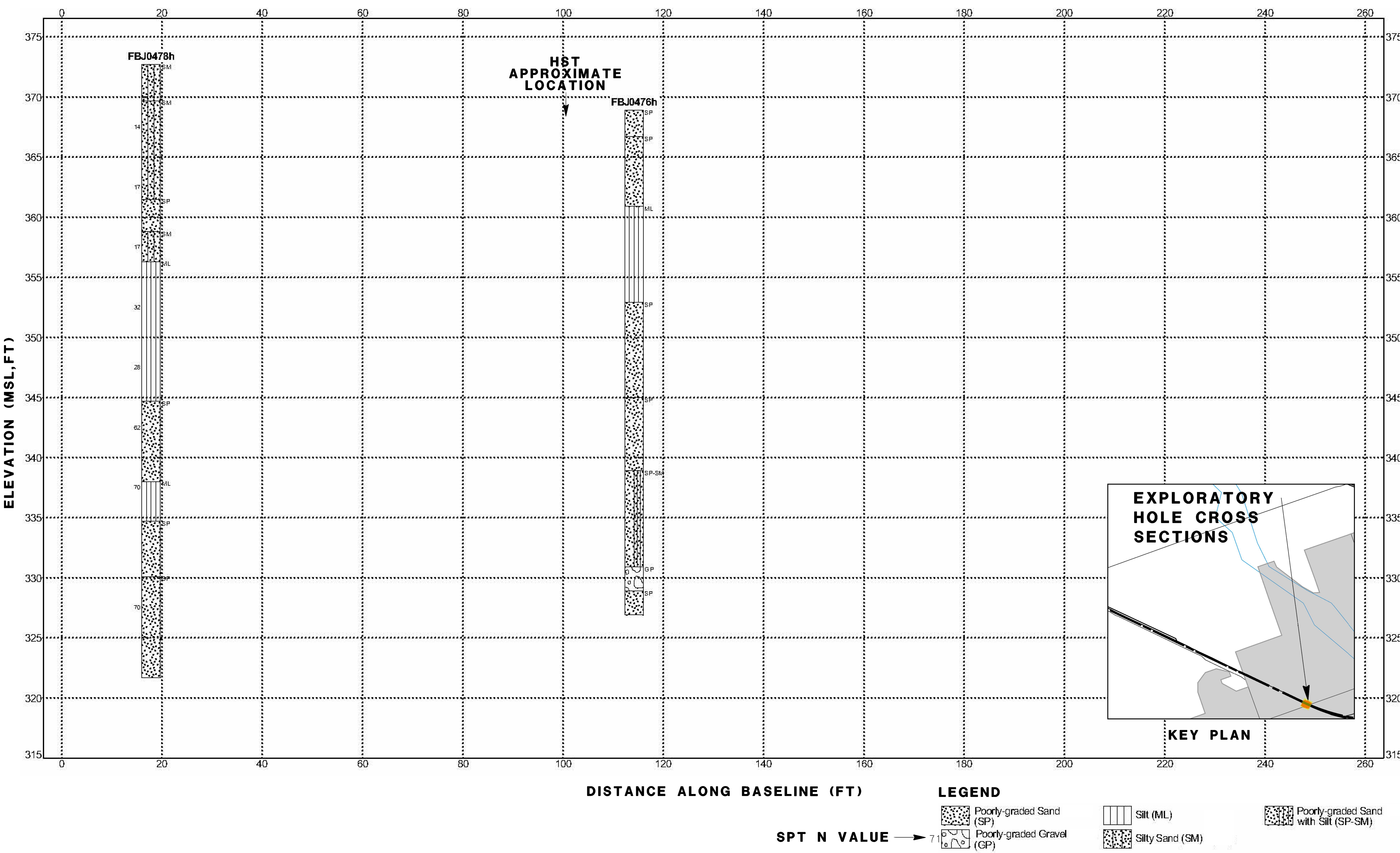
04/02/2014 - RFP No.: HSR13-57

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
STRATIGRAPHY: RURAL SOUTH (FB-G)

FIGURE NO. A15
DATE DECEMBER 2013
SHEET NO. 1 of 1



04/02/2014 - RFP No.: HSR13-57

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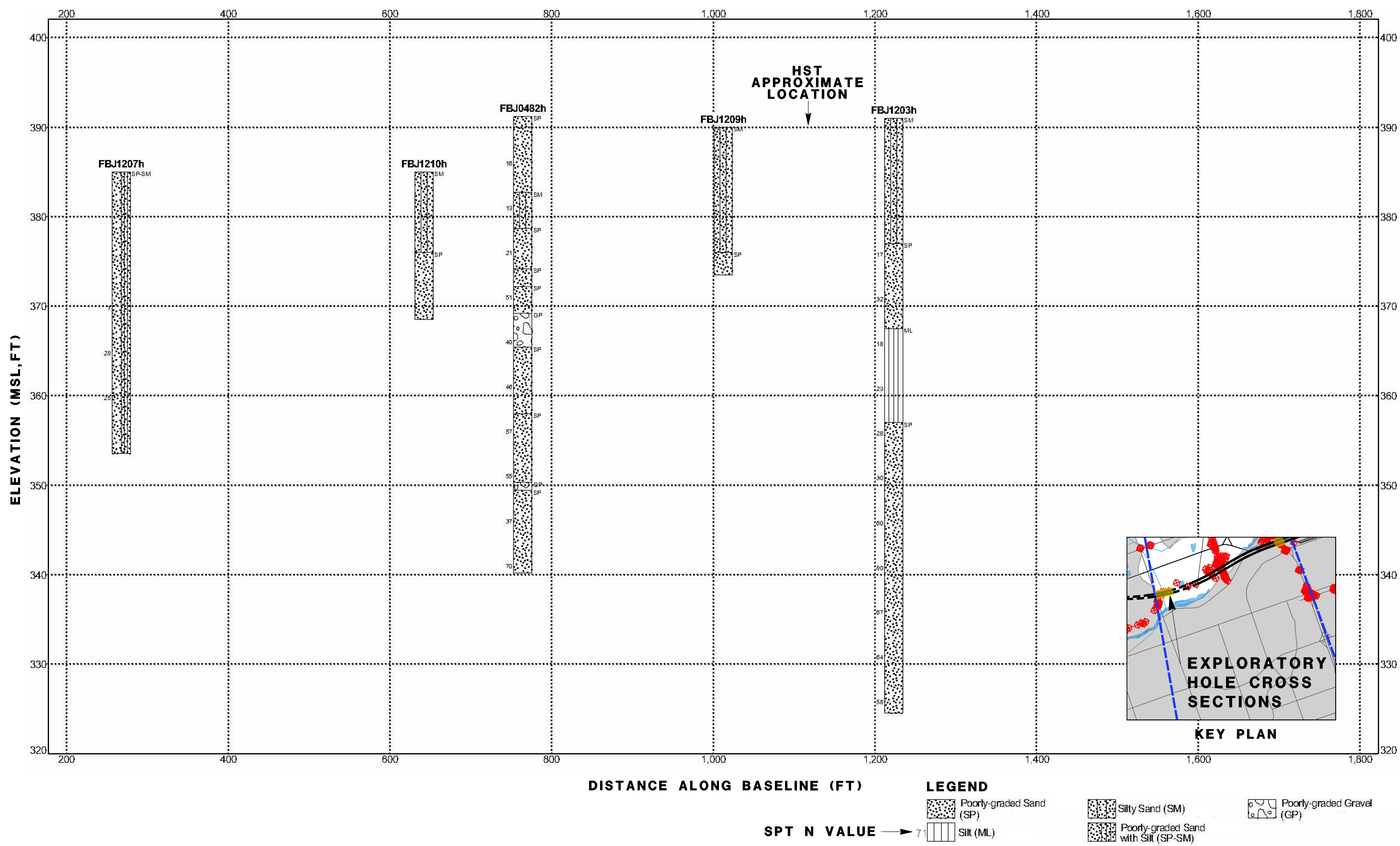
URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
STRATIGRAPHY: BAKERSFIELD NORTH (FB-J)

FIGURE NO.	A16
DATE	DECEMBER 2013
SHEET NO.	1 of 1

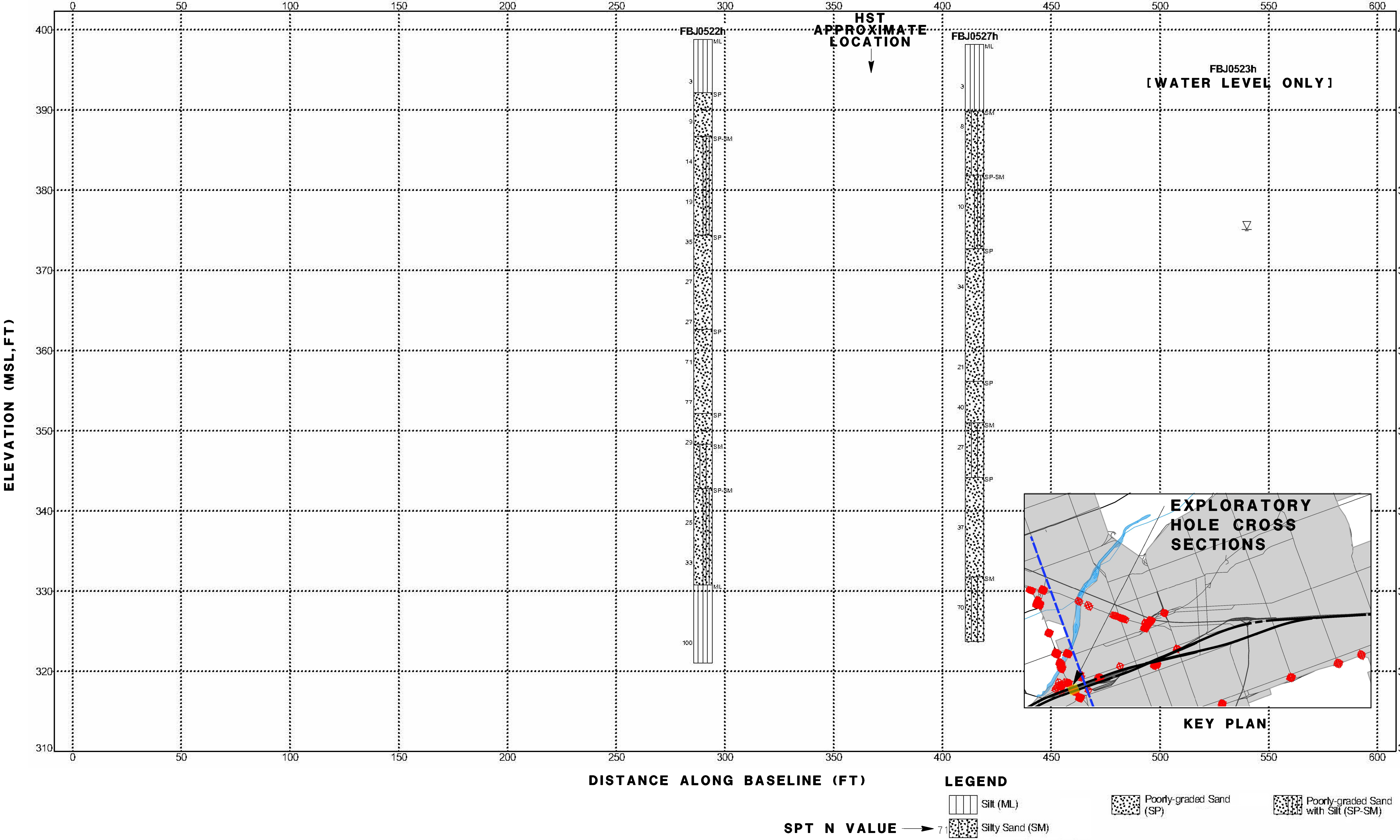


URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
STRATIGRAPHY: KERN RIVER CROSSING (FB-K)

FIGURE NO.	A17a
DATE	DECEMBER 2013
SHEET NO.	1 of 2



04/02/2014 - RFP No.: HSR13-57

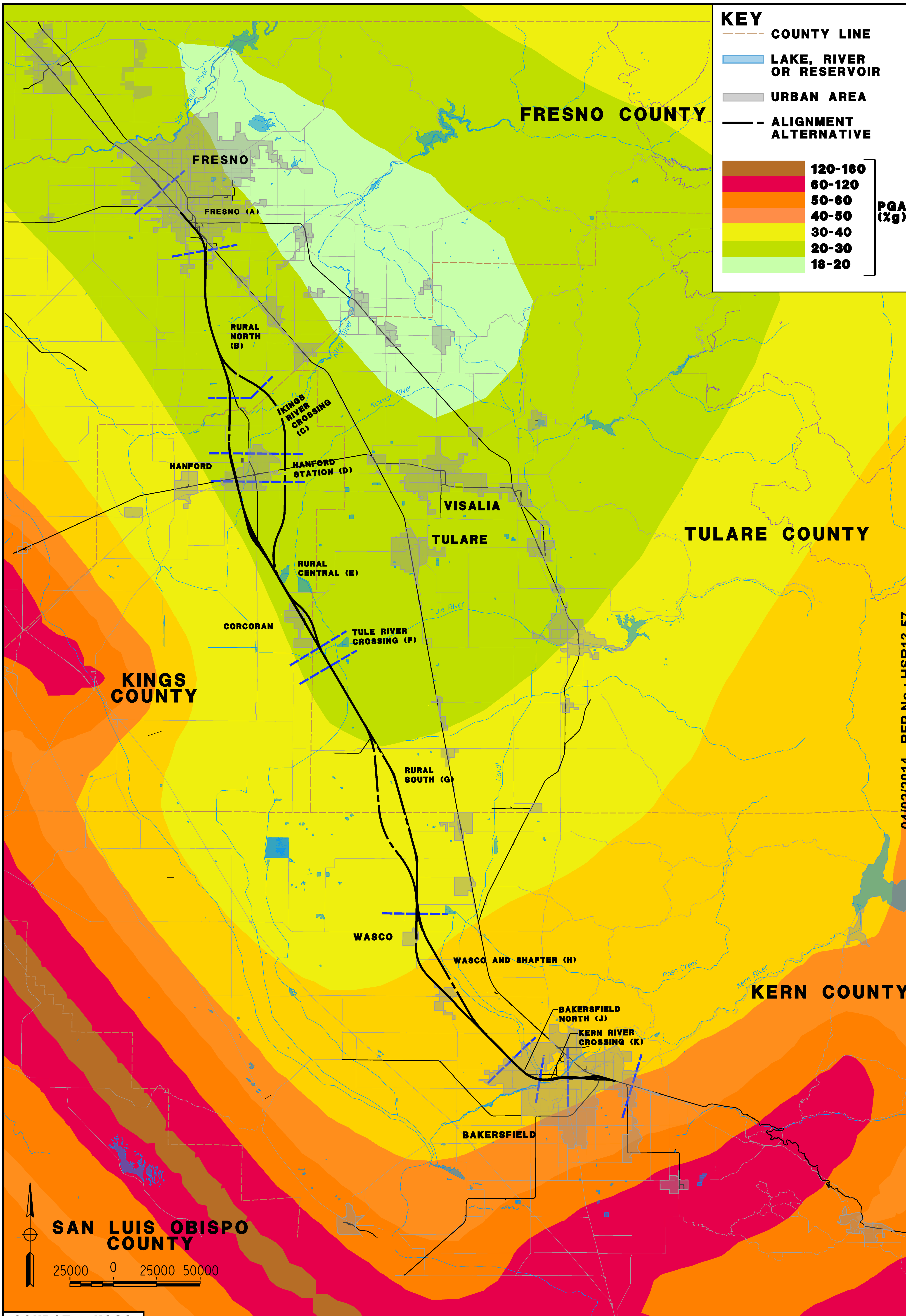
URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
STRATIGRAPHY: KERN RIVER CROSSING (FB-K)

FIGURE NO. A17b
DATE DECEMBER 2013
SHEET NO. 2 of 2

Jodi.Borghesi 12/16/2013 10:47:54 AM



URS | HMM | ARUP CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD

PEAK GROUND ACCELERATION (PGA)
2% PROBABILITY OF EXCEEDANCE
IN 50 YEARS - SITE CLASS B
(4% IN 100 YEARS ≈ 2% IN 50 YEARS)

FIGURE NO. A18a
DATE DECEMBER 2013
SHEET NO. 1 OF 3

\\global\americas\Jobs\S-F\31000\31577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\2012-01-11_ 15% Seismic & Geological Hazards\FB-GB-6017a.dgn
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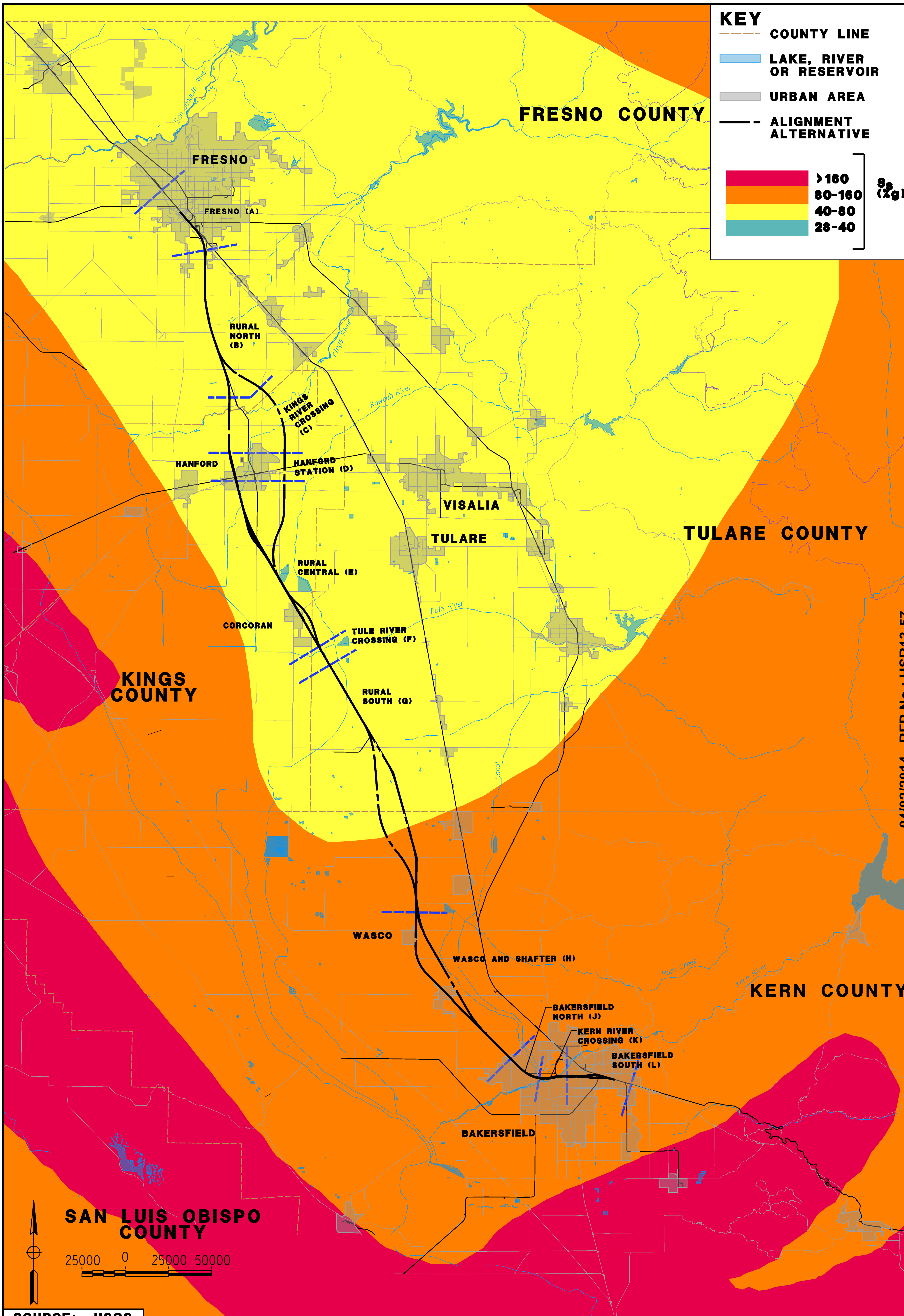

SOURCE: USGS

04/02/2014 - RFP No.: HSR13-57

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD

SHORT PERIOD RESPONSE SPECTRA AT 0.2 SEC WITH 2% PROBABILITY OF EXCEEDANCE IN 50 YEARS - SITE CLASS B (4% IN 100 YEARS ~ 2% IN 50 YEARS)

FIGURE NO.	A18b
DATE	DECEMBER 2013
SHEET NO.	2 OF 3

\\global\americas\Jobs\S-F\31000\31577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\2012-01-11_ 15% Seismic & Geological Hazards\FB-GB-6017b.dgn
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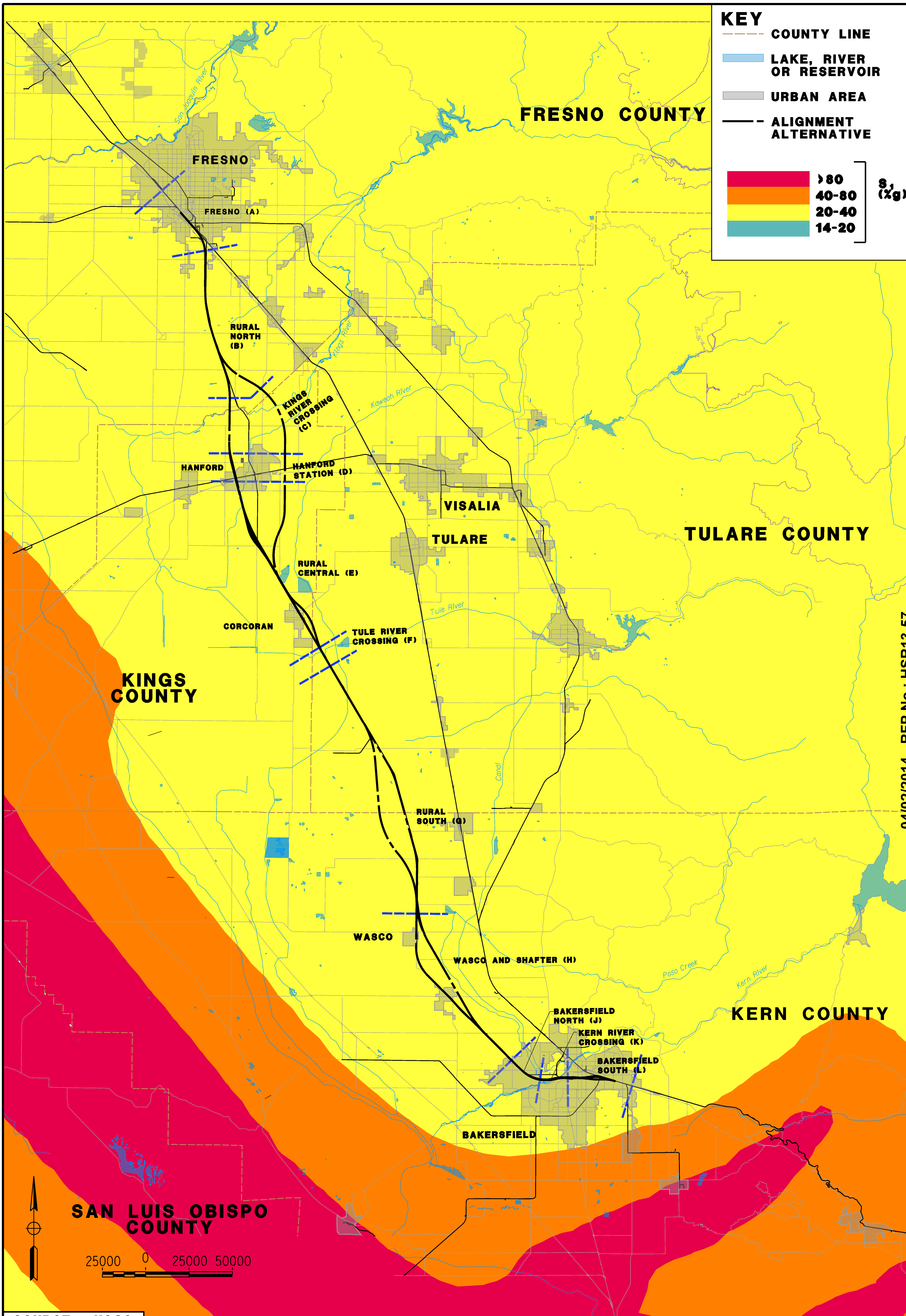


04/02/2014 - RFP No.: HSR13-57

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

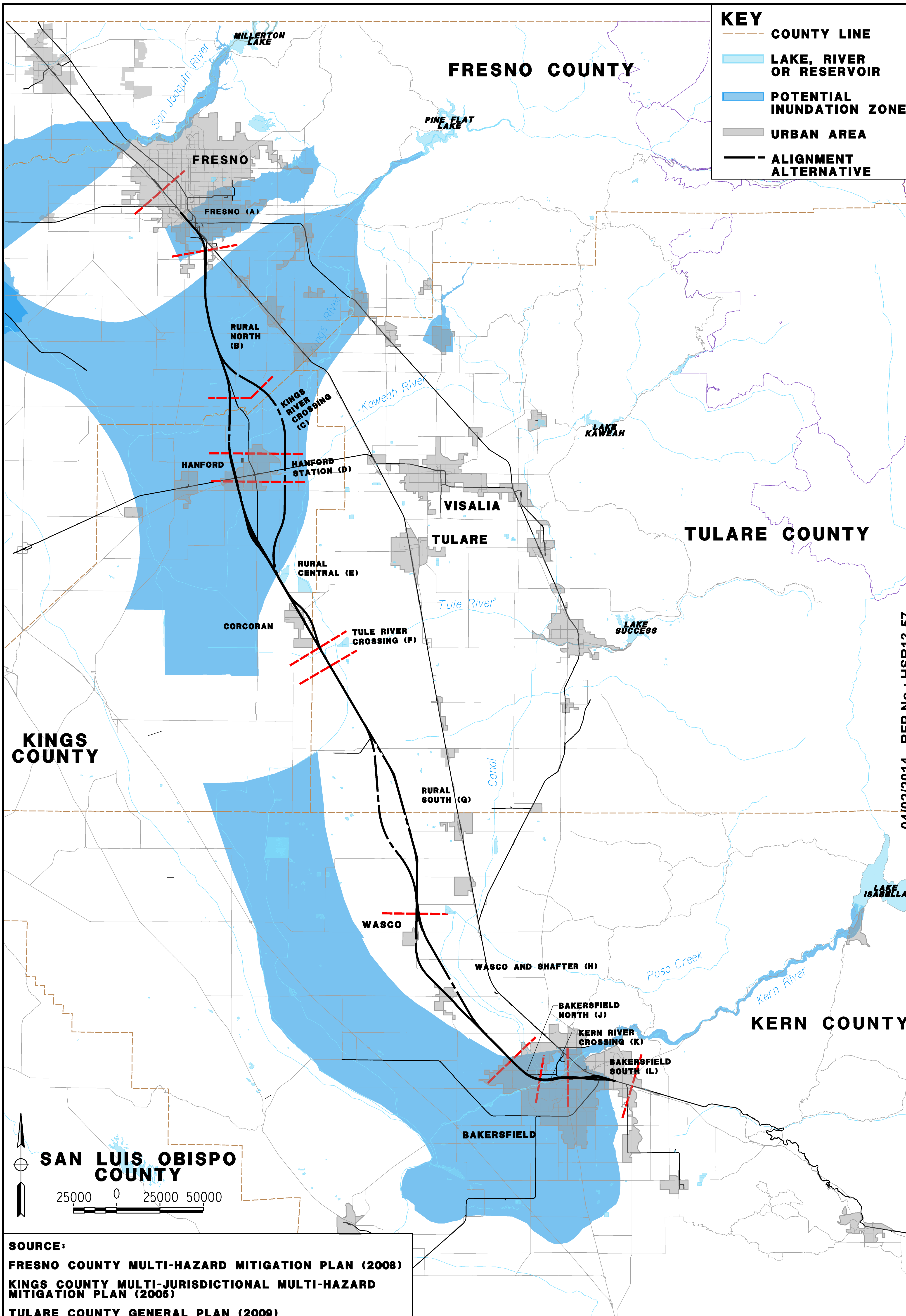
CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD

1-SEC PERIOD RESPONSE SPECTRUM WITH 2% PROBABILITY OF EXCEEDANCE IN 50 YEARS - SITE CLASS B (4% IN 100 YEARS ≈ 2% IN 50 YEARS)

FIGURE NO.	A18c
DATE	DECEMBER 2013
SHEET NO.	3 OF 3

\\global\americas\Jobs\S-F\31000\31577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\2012-01-11_ 15% Seismic & Geological Hazards\FB-GB-6017c.dgn
Jodi.Borghesi 10:53:11 AM



URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

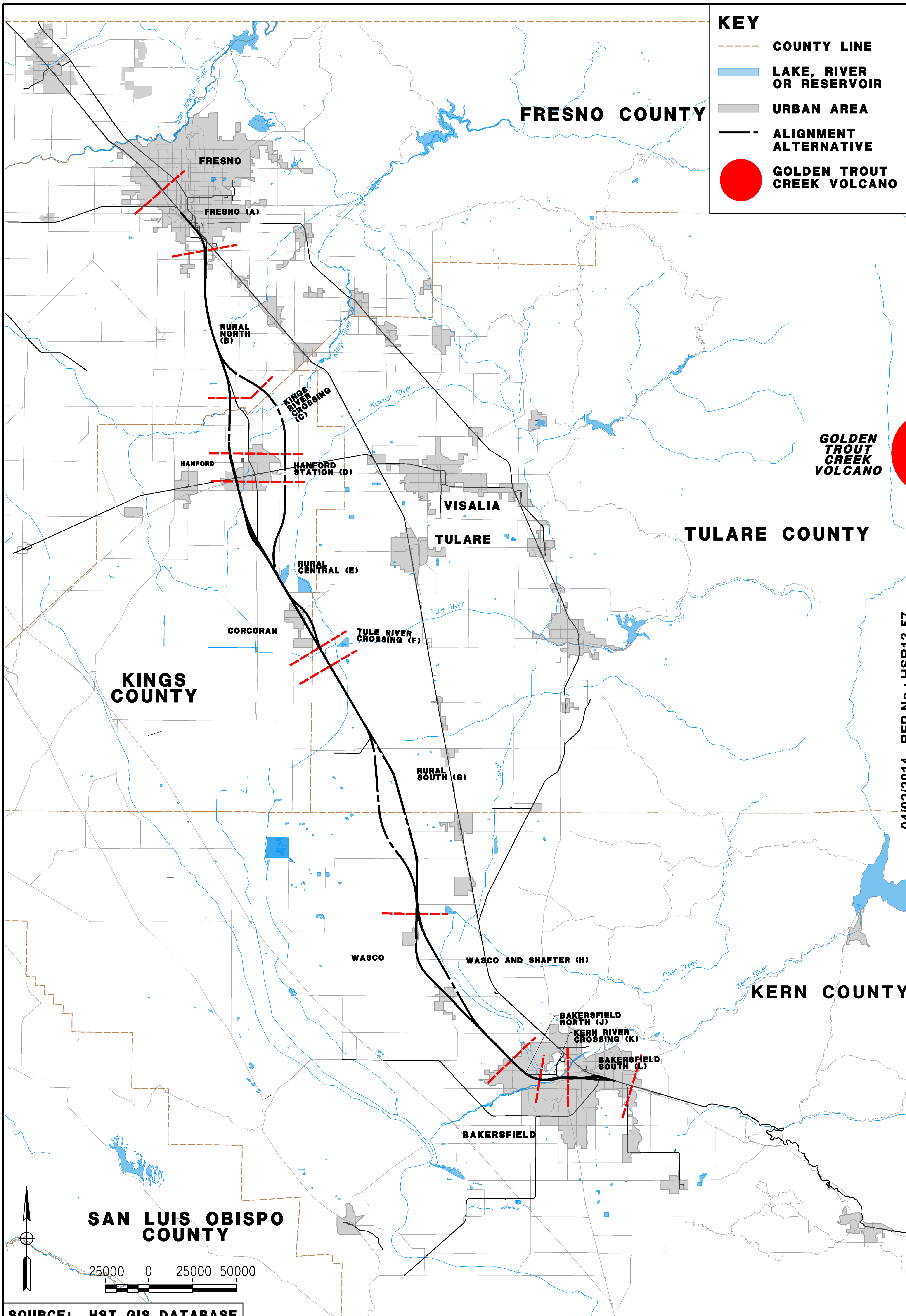
CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD

INUNDATION DUE TO
CATASTROPHIC DAM FAILURES

FIGURE NO.	A19
DATE	DECEMBER 2013
SHEET NO.	1 OF 1

\\global\americas\Jobs\S-F\31000\31577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\2012-01-11_ 15% Seismic & Geological Hazards\FB-GB-6018.dgn
Jodi.Borghesi 10:54:00 AM



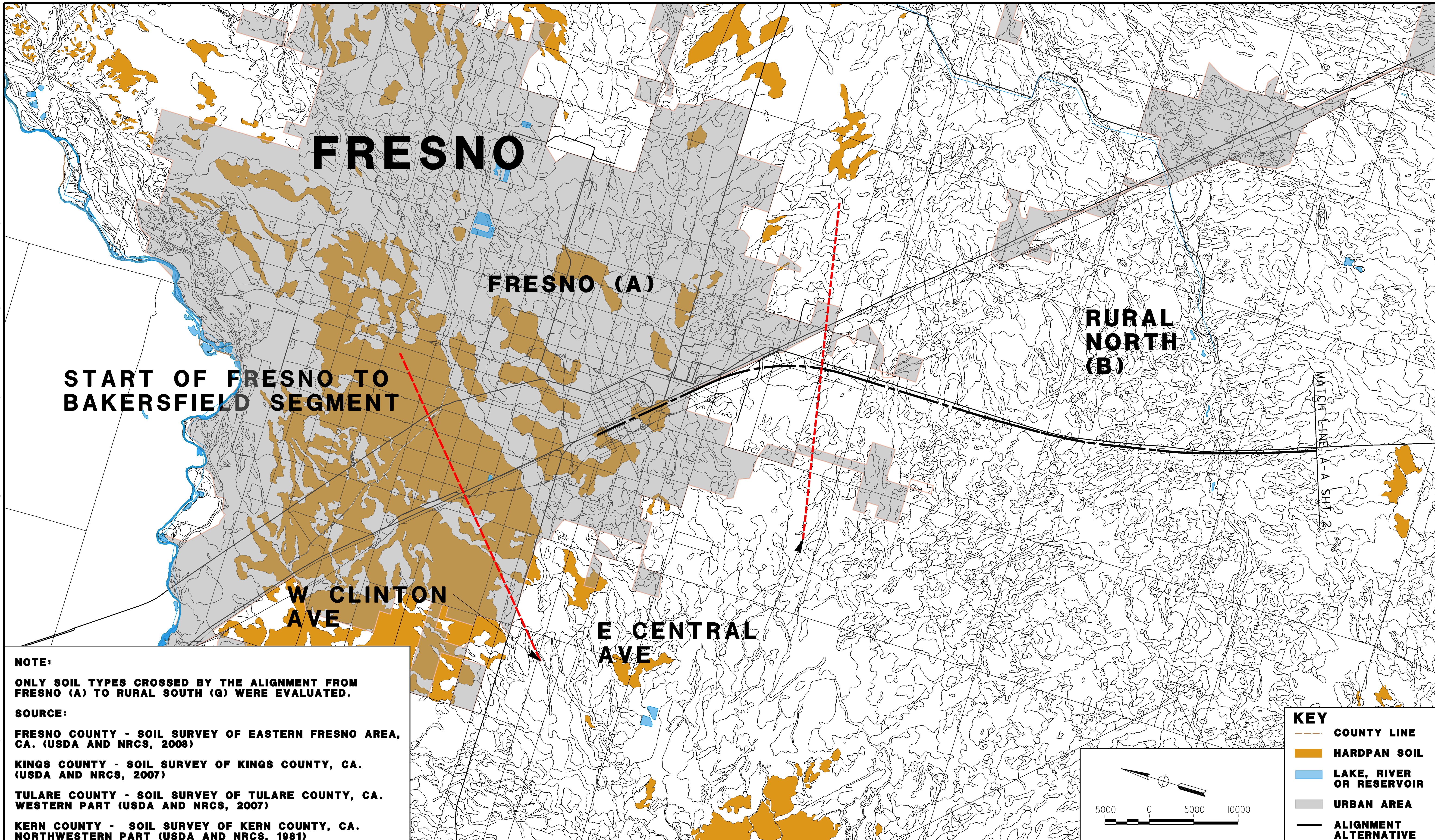
URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
VOLCANIC HAZARDS

FIGURE NO.	A20
DATE	DECEMBER 2013
SHEET NO.	1 OF 1

\\global\americas\Jobs\S-F\31000\31577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\2012-01-11_ 15% Seismic & Geological Hazards\FB-GB-6019.dgn
Jodi.Borghesi 10:56:47 AM



NOTE:

ONLY SOIL TYPES CROSSED BY THE ALIGNMENT FROM FRESNO (A) TO RURAL SOUTH (G) WERE EVALUATED.

SOURCE:

FRESNO COUNTY - SOIL SURVEY OF EASTERN FRESNO AREA, CA. (USDA AND NRCS, 2008)

KINGS COUNTY - SOIL SURVEY OF KINGS COUNTY, CA. (USDA AND NRCS, 2007)

TULARE COUNTY - SOIL SURVEY OF TULARE COUNTY, CA. WESTERN PART (USDA AND NRCS, 2007)

KERN COUNTY - SOIL SURVEY OF KERN COUNTY, CA. NORTHWESTERN PART (USDA AND NRCS, 1981)

KEY

- COUNTY LINE
- HARDPAN SOIL
- LAKE, RIVER OR RESERVOIR
- URBAN AREA
- ALIGNMENT ALTERNATIVE

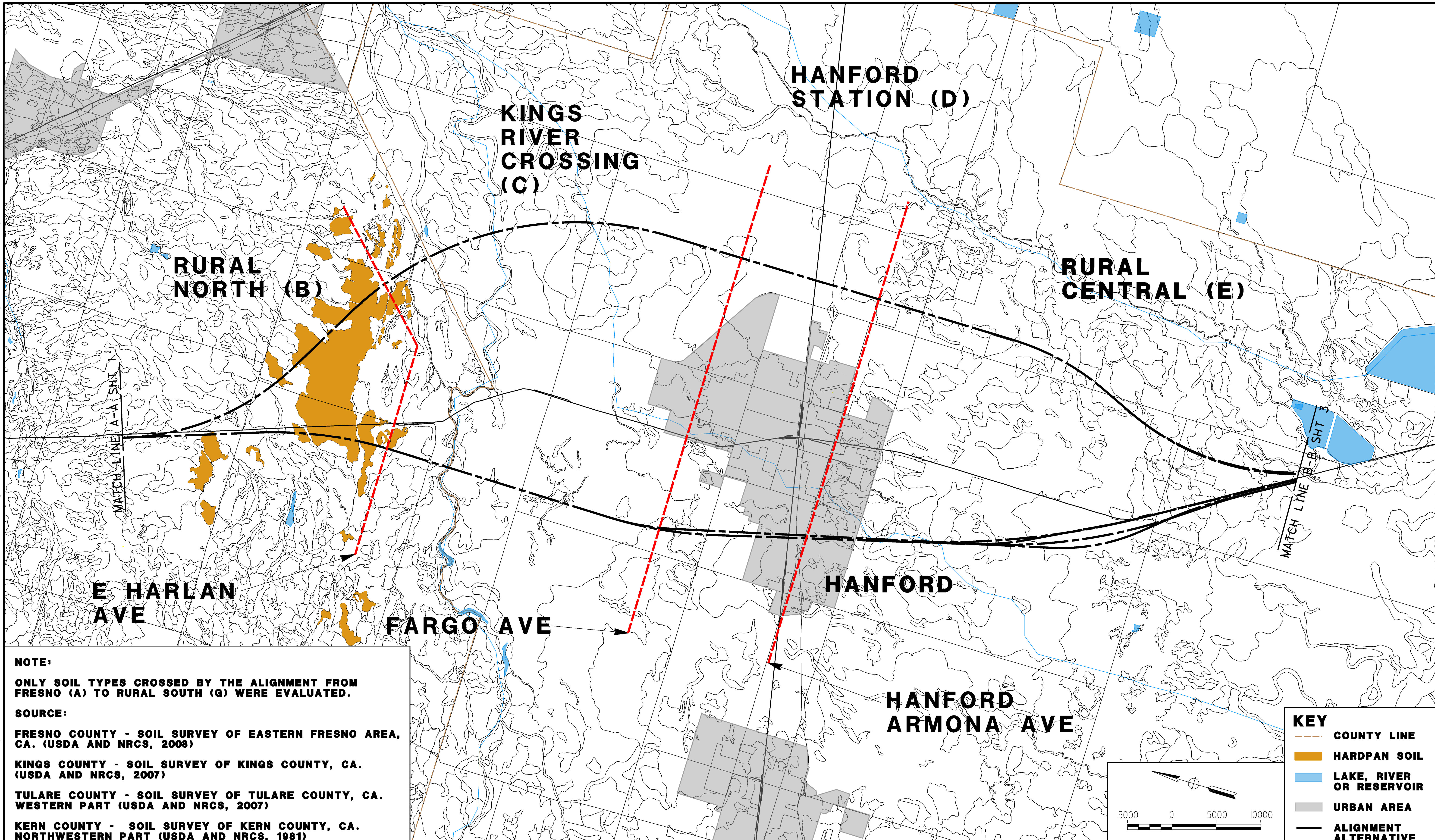
04/02/2014 - RFP No.: HSR13-57

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
AREAS OF DIFFICULT EXCAVATION: FB-A to FB-B

FIGURE NO.	A21a
DATE	DECEMBER 2013
SHEET NO.	1 of 5



NOTE:

ONLY SOIL TYPES CROSSED BY THE ALIGNMENT FROM FRESNO (A) TO RURAL SOUTH (G) WERE EVALUATED.

SOURCE:

FRESNO COUNTY - SOIL SURVEY OF EASTERN FRESNO AREA, CA. (USDA AND NRCS, 2008)

KINGS COUNTY - SOIL SURVEY OF KINGS COUNTY, CA. (USDA AND NRCS, 2007)

TULARE COUNTY - SOIL SURVEY OF TULARE COUNTY, CA. WESTERN PART (USDA AND NRCS, 2007)

KERN COUNTY - SOIL SURVEY OF KERN COUNTY, CA. NORTHWESTERN PART (USDA AND NRCS, 1981)

04/02/2014 - RFP No.: HSR13-57

Jodi.Borghesi 12/20/2013 9:56:25 AM \\global\americas\Jobs\S-F\131000\131577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\2012-01-11_ 15% Seismic & Geologic

URS | HMM | ARUP CALIFORNIA HIGH-SPEED TRAIN

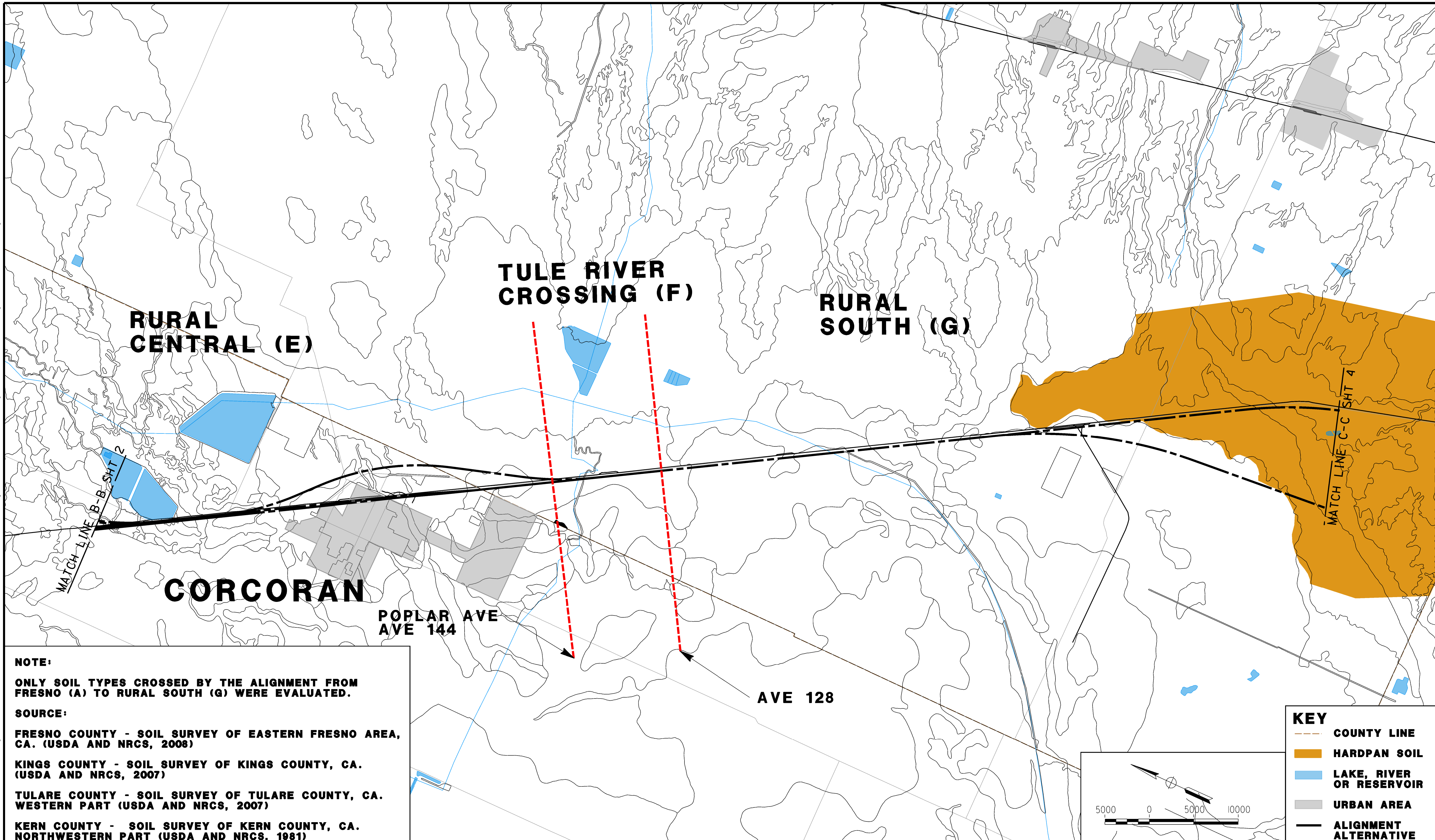
CALIFORNIA HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
AREAS OF DIFFICULT EXCAVATION: FB-B to FB-E

FIGURE NO. A21b

DATE DECEMBER 2013

SHEET NO. 2 of 5



NOTE:

ONLY SOIL TYPES CROSSED BY THE ALIGNMENT FROM FRESNO (A) TO RURAL SOUTH (G) WERE EVALUATED.

SOURCE:

FRESNO COUNTY - SOIL SURVEY OF EASTERN FRESNO AREA, CA. (USDA AND NRCS, 2008)

KINGS COUNTY - SOIL SURVEY OF KINGS COUNTY, CA. (USDA AND NRCS, 2007)

TULARE COUNTY - SOIL SURVEY OF TULARE COUNTY, CA. WESTERN PART (USDA AND NRCS, 2007)

KERN COUNTY - SOIL SURVEY OF KERN COUNTY, CA. NORTHWESTERN PART (USDA AND NRCS, 1981)

KEY

- COUNTY LINE
- HARDPAN SOIL
- LAKE, RIVER OR RESERVOIR
- URBAN AREA
- ALIGNMENT ALTERNATIVE

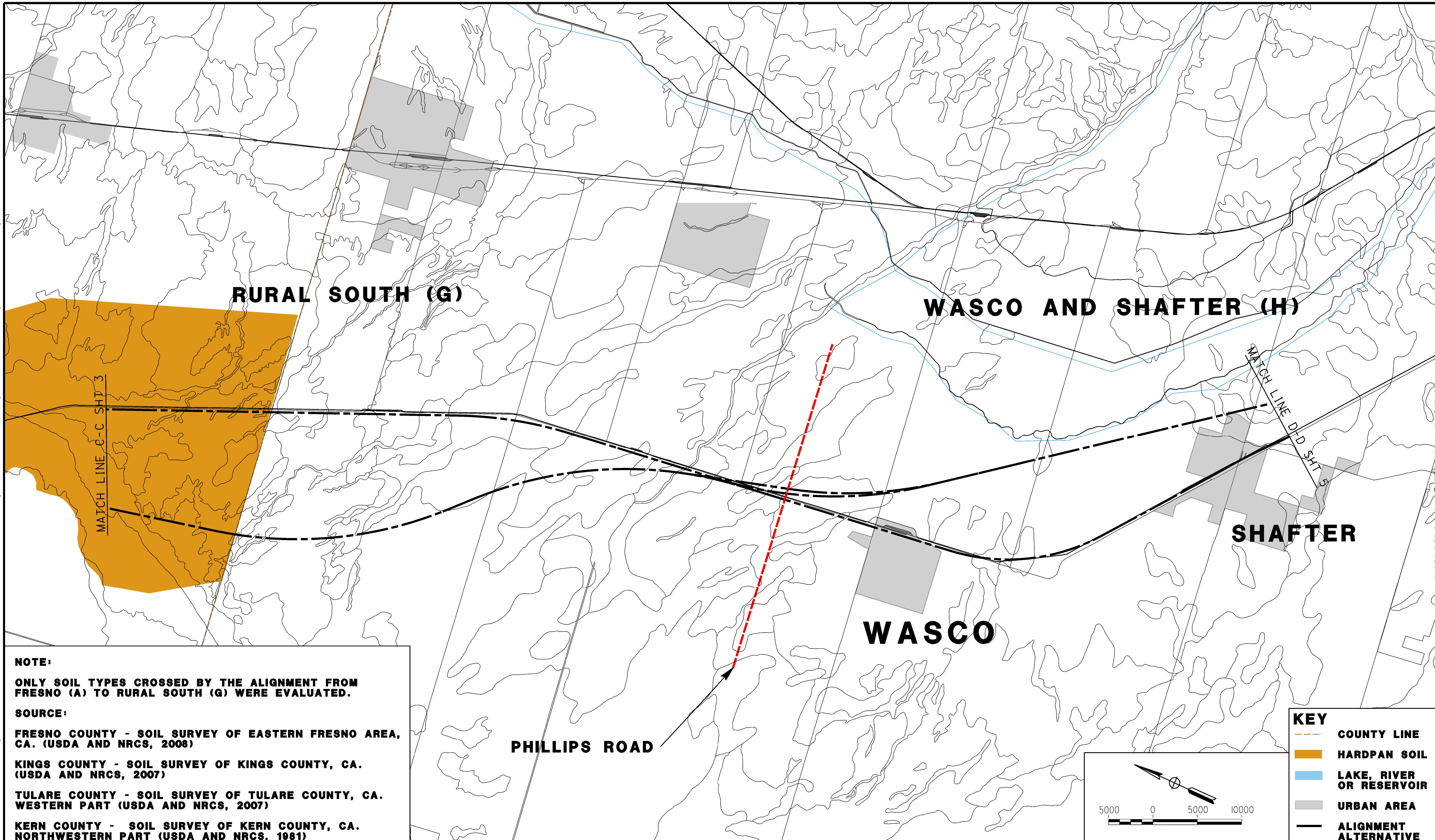
URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
AREAS OF DIFFICULT EXCAVATION: FB-G

FIGURE NO.	A21c
DATE	DECEMBER 2013
SHEET NO.	3 of 5

04/02/2014 - RFP No.: HSR13-57



NOTE:

ONLY SOIL TYPES CROSSED BY THE ALIGNMENT FROM FRESNO (A) TO RURAL SOUTH (G) WERE EVALUATED.

SOURCE:

FRESNO COUNTY - SOIL SURVEY OF EASTERN FRESNO AREA, CA. (USDA AND NRCS, 2008)

KINGS COUNTY - SOIL SURVEY OF KINGS COUNTY, CA. (USDA AND NRCS, 2007)

TULARE COUNTY - SOIL SURVEY OF TULARE COUNTY, CA. WESTERN PART (USDA AND NRCS, 2007)

KERN COUNTY - SOIL SURVEY OF KERN COUNTY, CA. NORTHWESTERN PART (USDA AND NRCS, 1981)

KEY

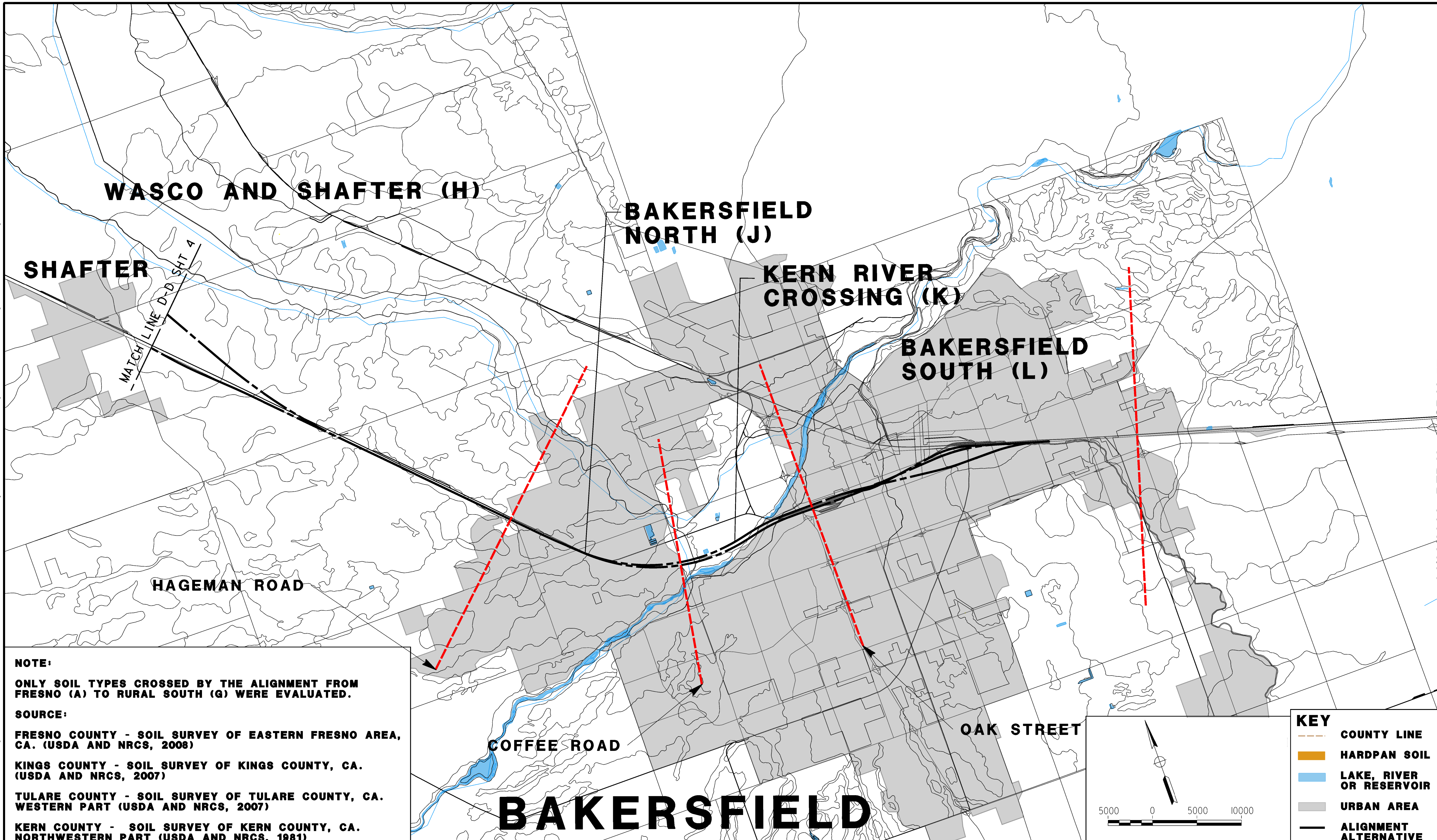
- COUNTY LINE
- HARDPAN SOIL
- LAKE, RIVER OR RESERVOIR
- URBAN AREA
- ALIGNMENT ALTERNATIVE

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
AREAS OF DIFFICULT EXCAVATION: FB-G to FB-H

FIGURE NO. A21d
DATE DECEMBER 2013
SHEET NO. 4 of 5



NOTE:

ONLY SOIL TYPES CROSSED BY THE ALIGNMENT FROM FRESNO (A) TO RURAL SOUTH (G) WERE EVALUATED.

SOURCE:

FRESNO COUNTY - SOIL SURVEY OF EASTERN FRESNO AREA, CA. (USDA AND NRCS, 2008)

KINGS COUNTY - SOIL SURVEY OF KINGS COUNTY, CA. (USDA AND NRCS, 2007)

TULARE COUNTY - SOIL SURVEY OF TULARE COUNTY, CA. WESTERN PART (USDA AND NRCS, 2007)

KERN COUNTY - SOIL SURVEY OF KERN COUNTY, CA. NORTHWESTERN PART (USDA AND NRCS, 1981)

KEY

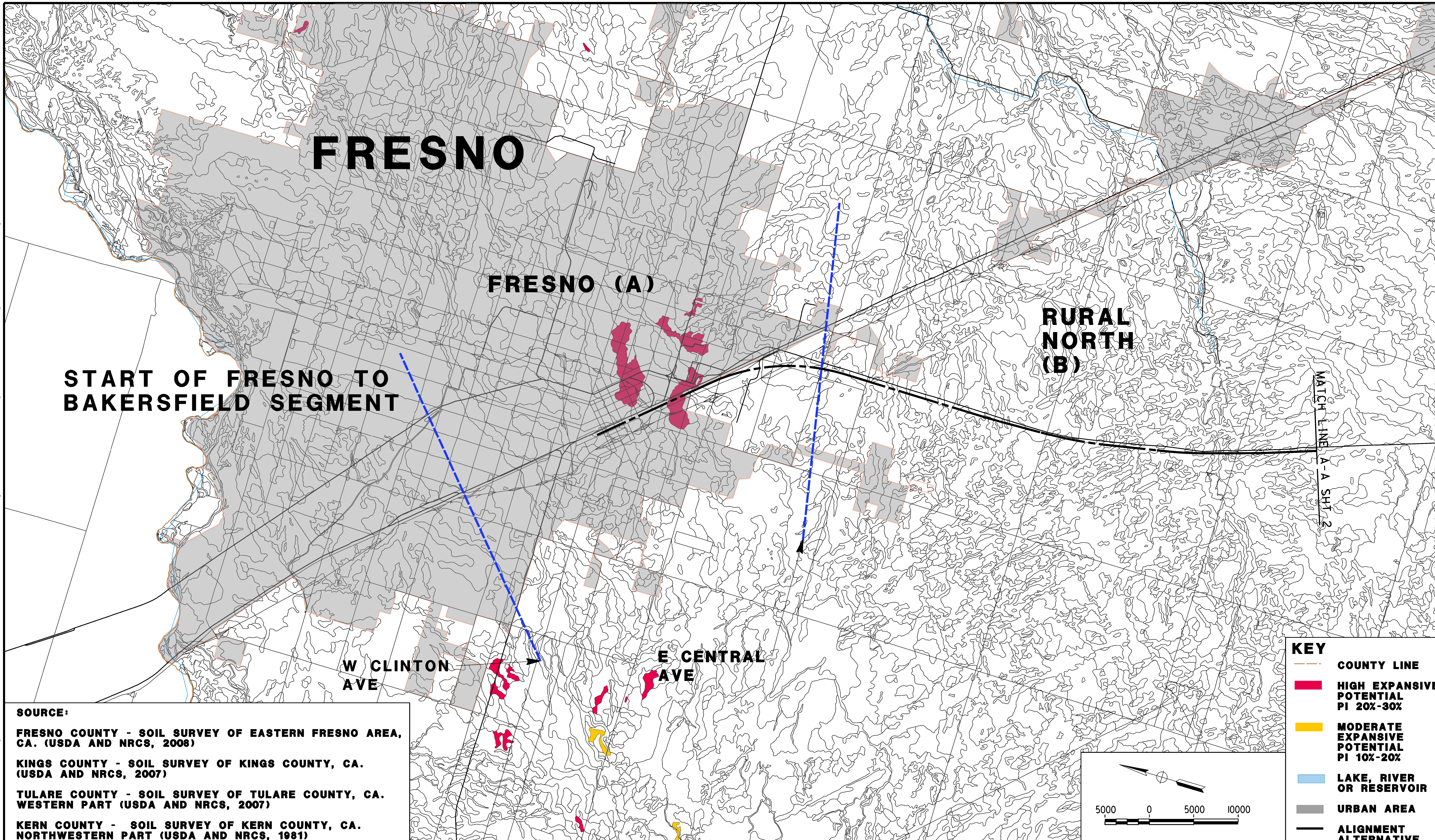
- COUNTY LINE
- HARDPAN SOIL
- LAKE, RIVER OR RESERVOIR
- URBAN AREA
- ALIGNMENT ALTERNATIVE

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
AREAS OF DIFFICULT EXCAVATION: FB-H to FB-L

FIGURE NO.	A21e
DATE	DECEMBER 2013
SHEET NO.	5 of 5



SOURCE:

FRESNO COUNTY - SOIL SURVEY OF EASTERN FRESNO AREA, CA. (USDA AND NRCS, 2008)

KINGS COUNTY - SOIL SURVEY OF KINGS COUNTY, CA. (USDA AND NRCS, 2007)

TULARE COUNTY - SOIL SURVEY OF TULARE COUNTY, CA. WESTERN PART (USDA AND NRCS, 2007)

KERN COUNTY - SOIL SURVEY OF KERN COUNTY, CA. NORTHWESTERN PART (USDA AND NRCS, 1981)

04/02/2014 - RFP No.: HSR13-57

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

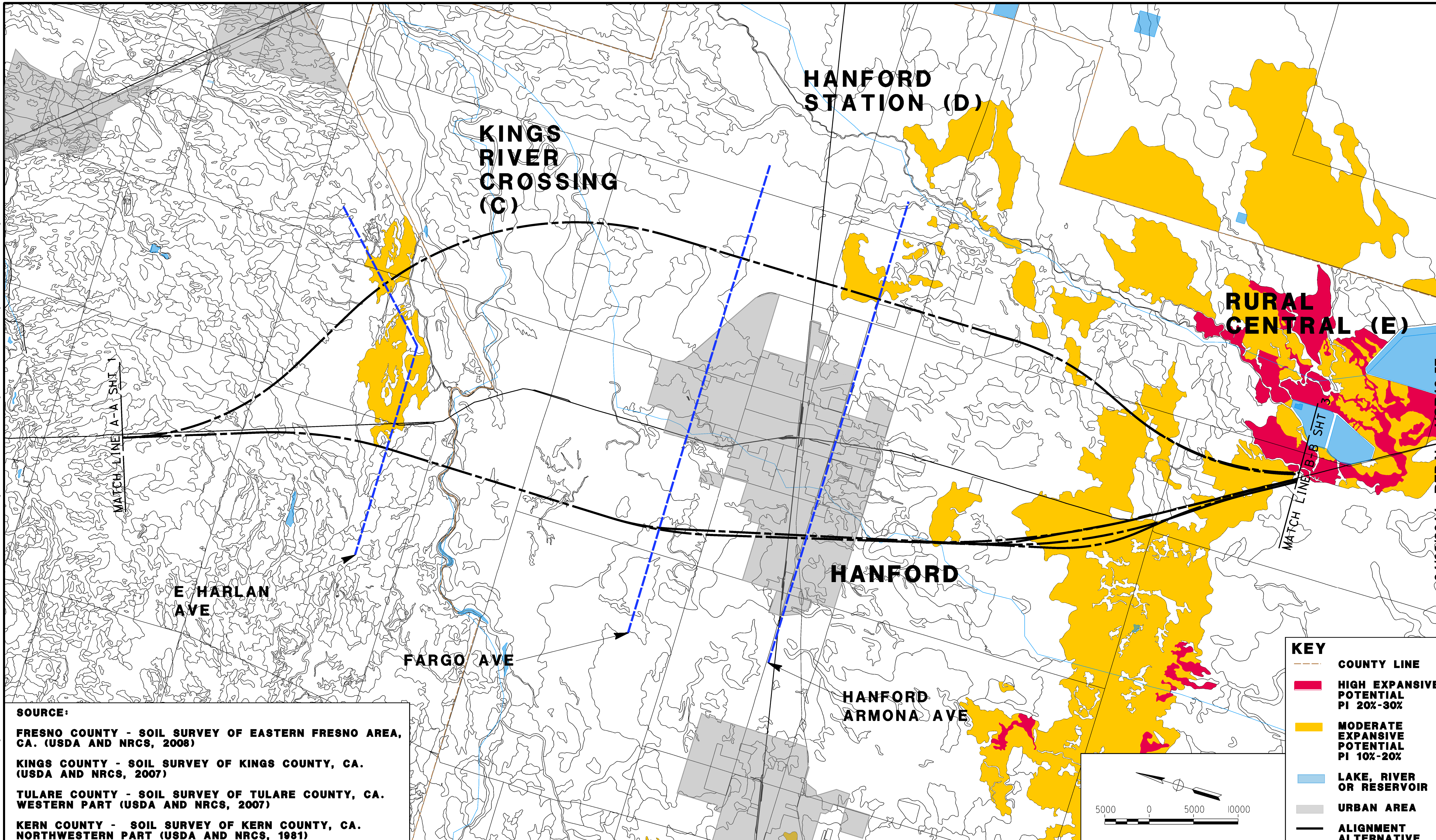
CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
EXPANSIVE SOILS: FB-A to FB-B

FIGURE NO. A22a

DATE DECEMBER 2013

SHEET NO. 1 of 5



SOURCE:

FRESNO COUNTY - SOIL SURVEY OF EASTERN FRESNO AREA, CA. (USDA AND NRCS, 2008)

KINGS COUNTY - SOIL SURVEY OF KINGS COUNTY, CA. (USDA AND NRCS, 2007)

TULARE COUNTY - SOIL SURVEY OF TULARE COUNTY, CA. WESTERN PART (USDA AND NRCS, 2007)

KERN COUNTY - SOIL SURVEY OF KERN COUNTY, CA. NORTHWESTERN PART (USDA AND NRCS, 1981)

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
EXPANSIVE SOILS: FB-B to FB-E

FIGURE NO. A22b
DATE DECEMBER 2013
SHEET NO. 2 of 5

04/02/2014 - RFP No.: HSR13-57

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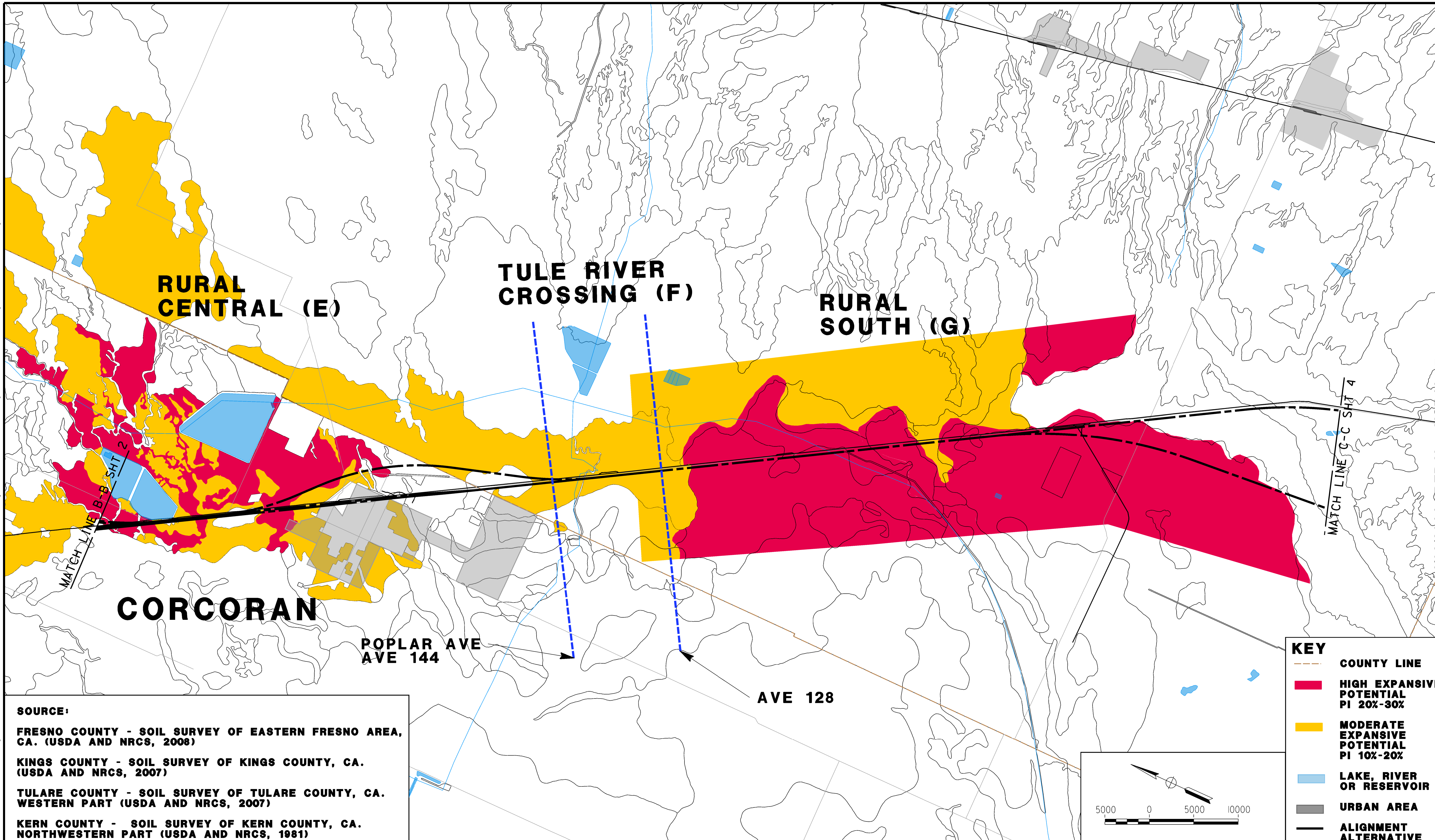


SOURCE:

FRESNO COUNTY - SOIL SURVEY OF EASTERN FRESNO AREA, CA. (USDA AND NRCS, 2008)

KINGS COUNTY - SOIL SURVEY OF KINGS COUNTY, CA. (USDA AND NRCS, 2007)

TULARE COUNTY - SOIL SURVEY OF TULARE COUNTY, CA. WESTERN PART (USDA AND NRCS, 2007)

KERN COUNTY - SOIL SURVEY OF KERN COUNTY, CA. NORTHWESTERN PART (USDA AND NRCS, 1981)

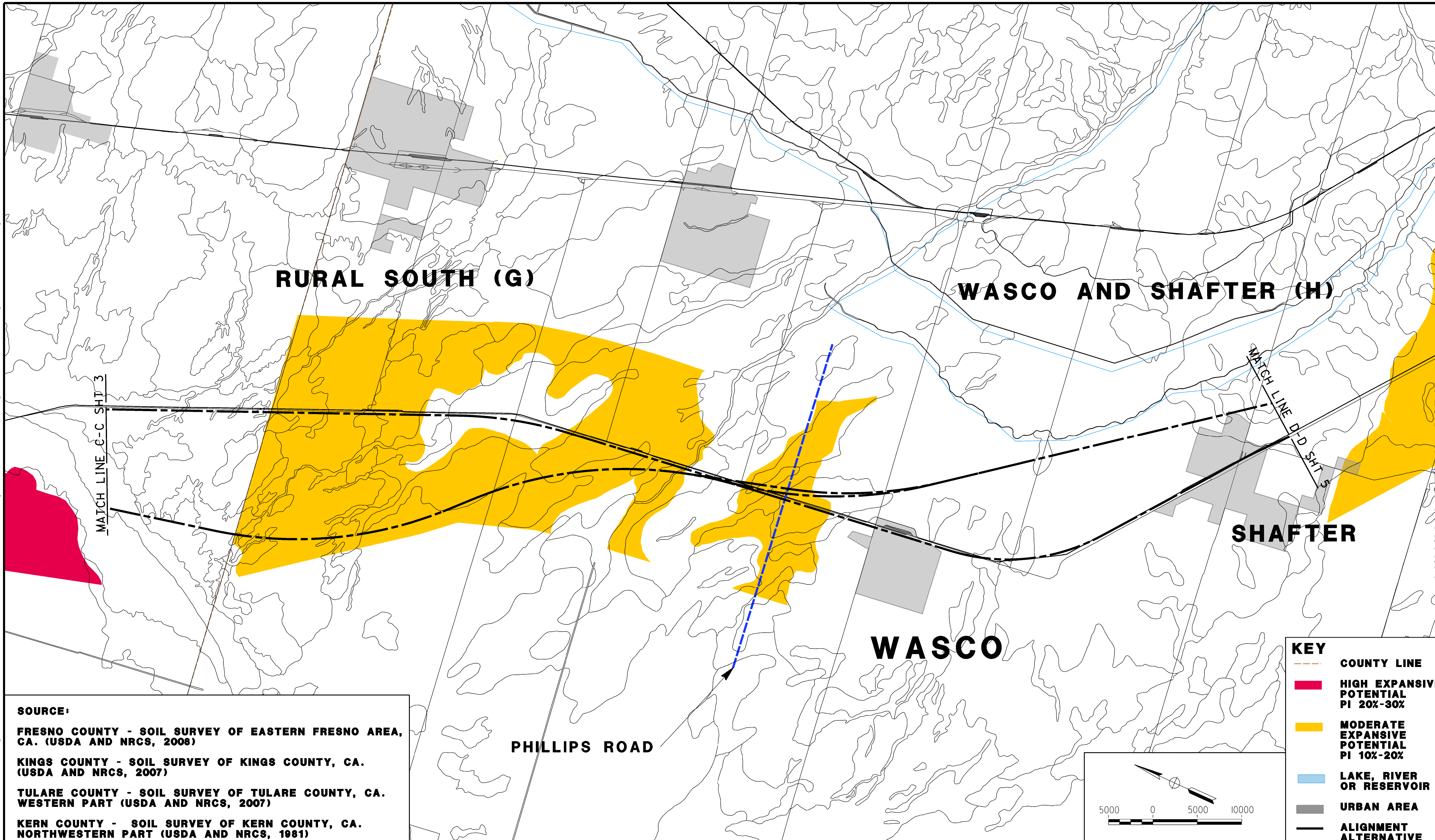
URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
EXPANSIVE SOILS: FB-E to FB-G

FIGURE NO.	A22c
DATE	DECEMBER 2013
SHEET NO.	3 of 5

04/02/2014 - RFP No.: HSR13-57



SOURCE:

FRESNO COUNTY - SOIL SURVEY OF EASTERN FRESNO AREA, CA. (USDA AND NRCS, 2008)

KINGS COUNTY - SOIL SURVEY OF KINGS COUNTY, CA. (USDA AND NRCS, 2007)

TULARE COUNTY - SOIL SURVEY OF TULARE COUNTY, CA. WESTERN PART (USDA AND NRCS, 2007)

KERN COUNTY - SOIL SURVEY OF KERN COUNTY, CA. NORTHWESTERN PART (USDA AND NRCS, 1981)

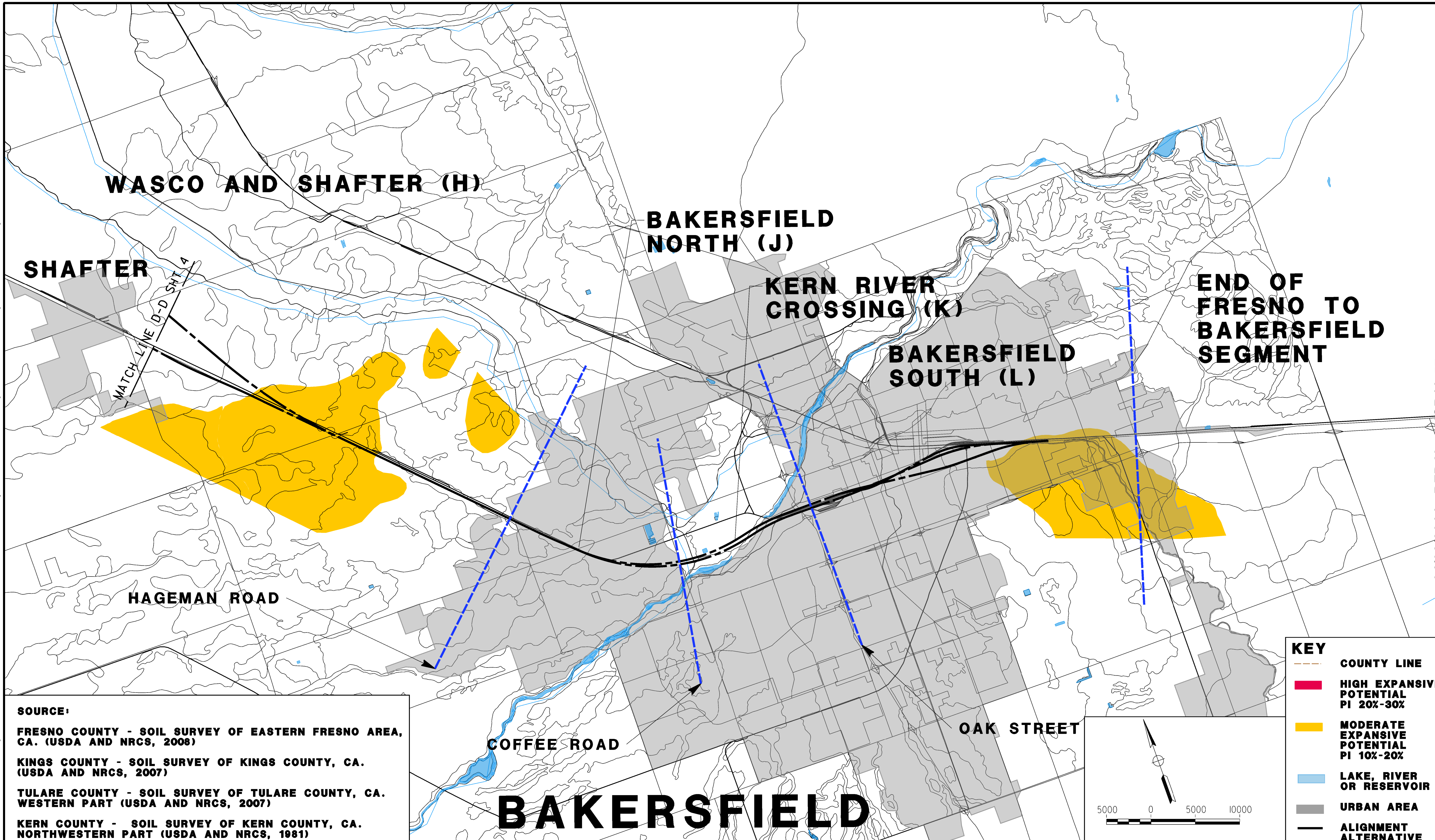
URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
EXPANSIVE SOILS: FB-G to FB-H

FIGURE NO. A22d
DATE DECEMBER 2013
SHEET NO. 4 of 5

04/02/2014 - RFP No.: HSR13-57



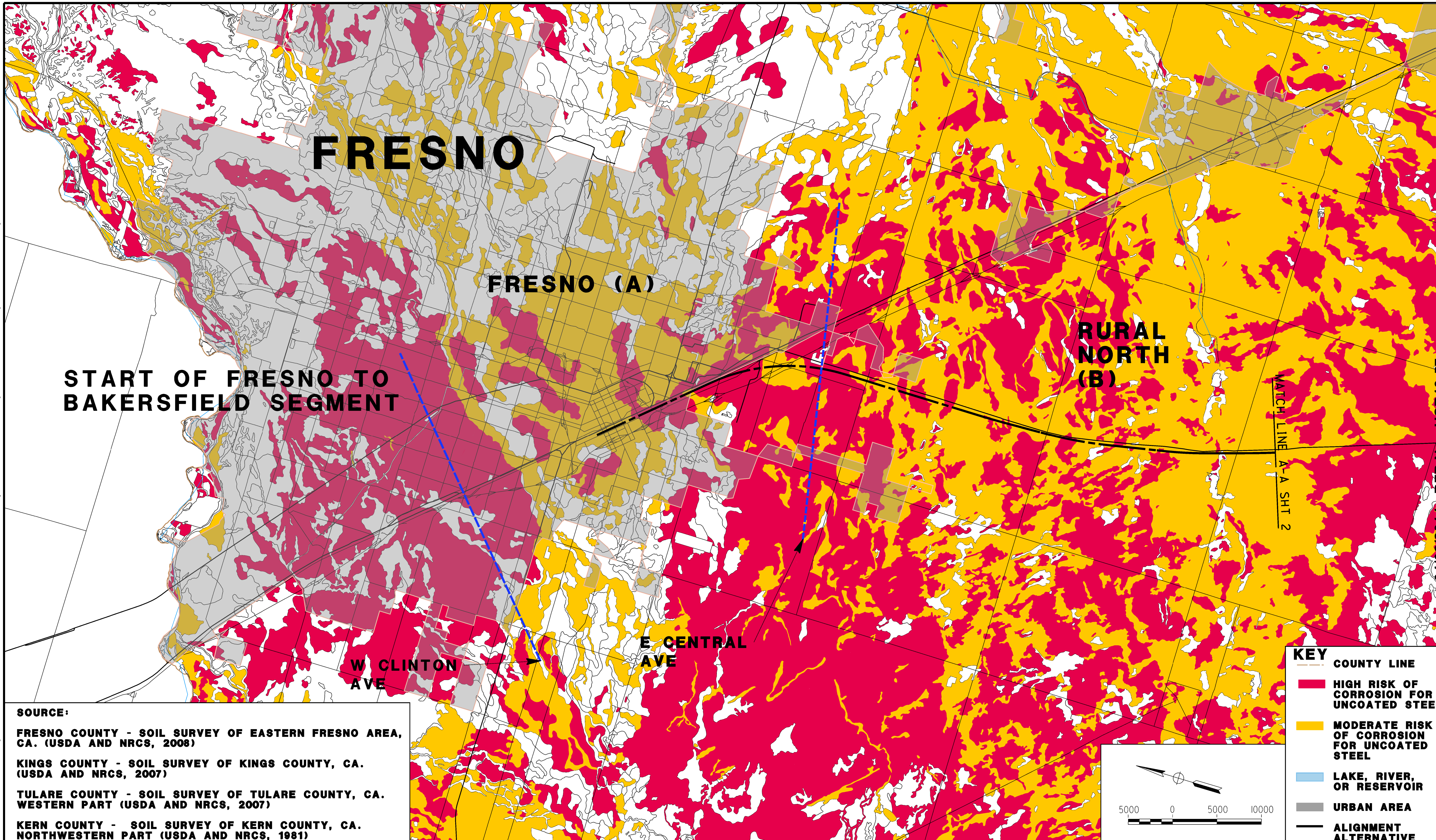
04/02/2014 - RFP No.: HSR13-57

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
EXPANSIVE SOILS: FB-H to FB-L

FIGURE NO. A22e
DATE DECEMBER 2013
SHEET NO. 5 of 5



SOURCE:

FRESNO COUNTY - SOIL SURVEY OF EASTERN FRESNO AREA, CA. (USDA AND NRCS, 2008)

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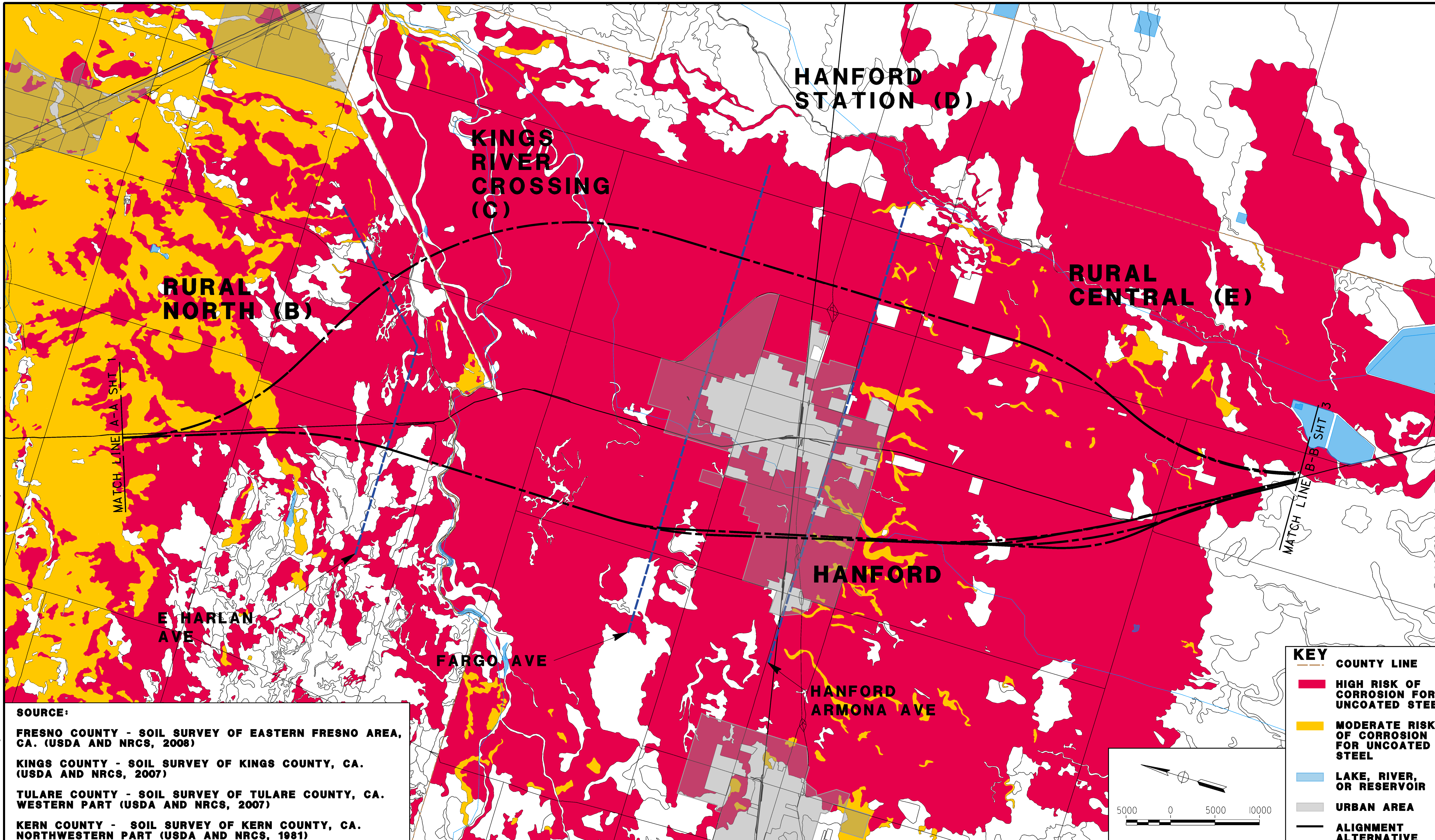
KERN COUNTY - SOIL SURVEY OF KERN COUNTY, CA. NORTHWESTERN PART (USDA AND NRCS, 1981)

URS | HMM | ARUP CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
SOIL CORROSIVITY-UNCOATED STEEL: FB-A to FB-B

FIGURE NO.	A23a
DATE	DECEMBER 2013
SHEET NO.	1 of 5

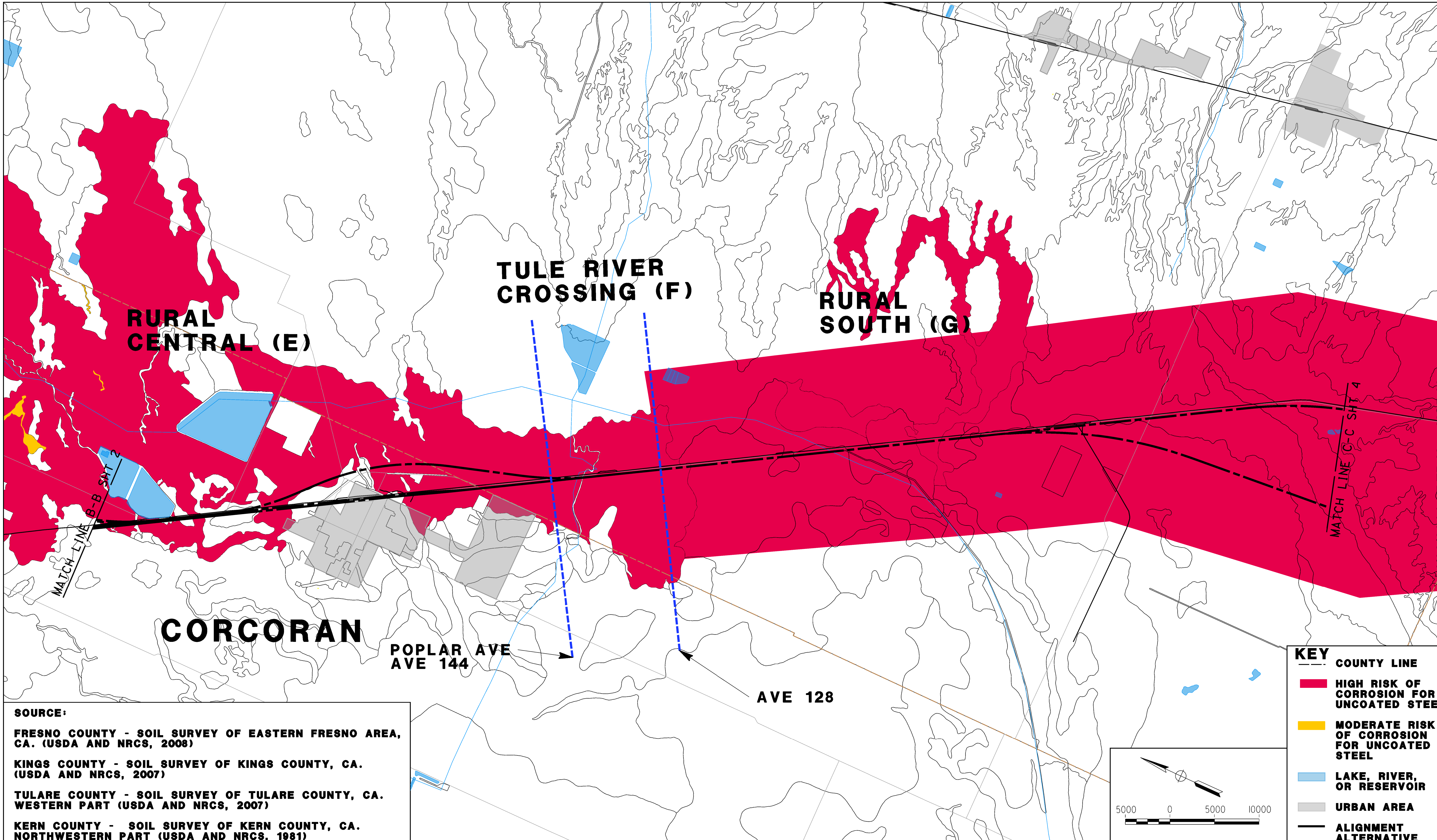


URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
SOIL CORROSIVITY-UNCOATED STEEL: FB-B to FB-E

FIGURE NO. A23b
DATE DECEMBER 2013
SHEET NO. 2 of 5



SOURCE:

FRESNO COUNTY - SOIL SURVEY OF EASTERN FRESNO AREA, CA. (USDA AND NRCS, 2008)

KINGS COUNTY - SOIL SURVEY OF KINGS COUNTY, CA. (USDA AND NRCS, 2007)

TULARE COUNTY - SOIL SURVEY OF TULARE COUNTY, CA. WESTERN PART (USDA AND NRCS, 2007)

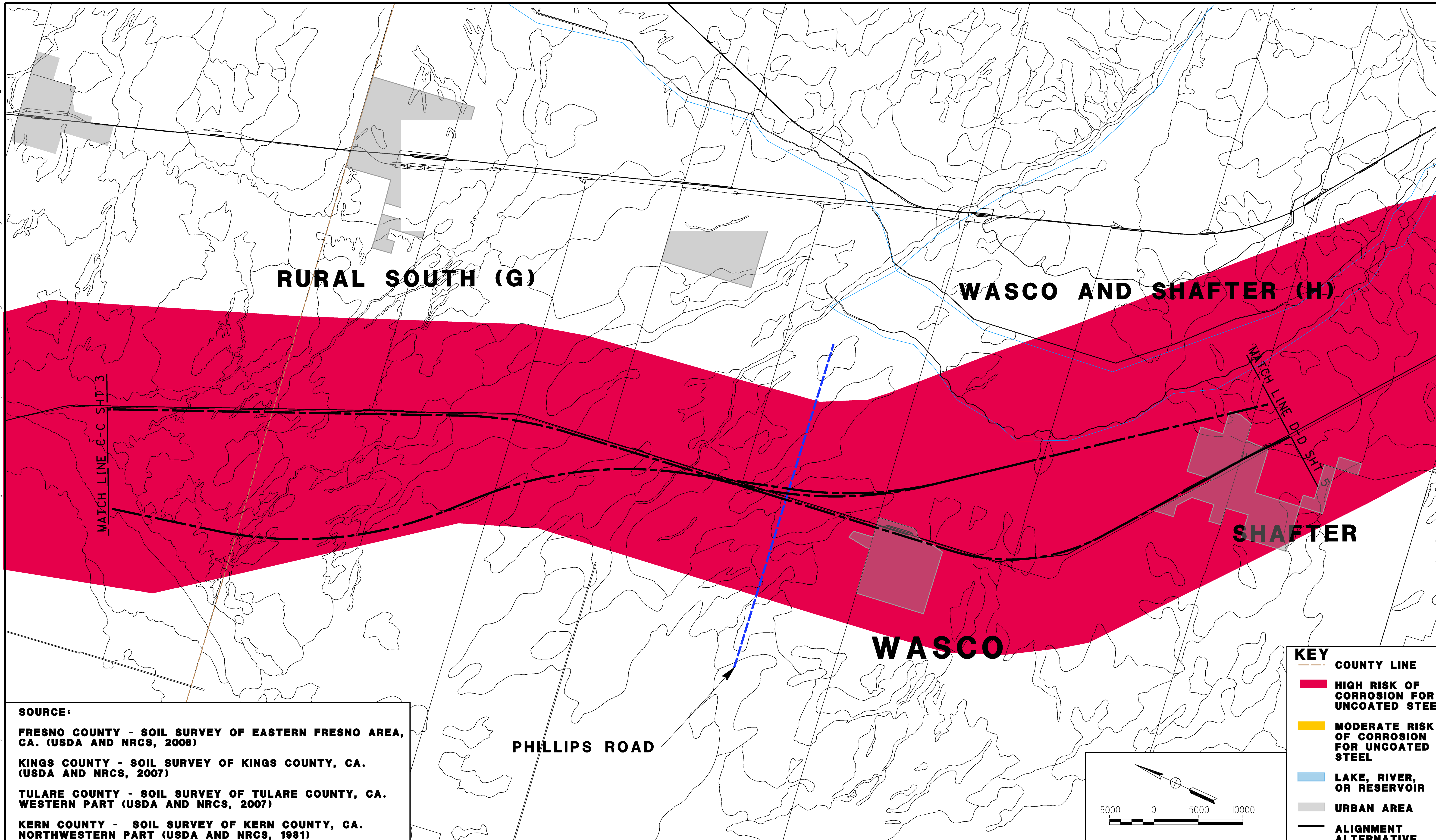
KERN COUNTY - SOIL SURVEY OF KERN COUNTY, CA. NORTHWESTERN PART (USDA AND NRCS, 1981)

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
SOIL CORROSIVITY-UNCOATED STEEL: FB-E to FB-G

FIGURE NO. A23c
DATE DECEMBER 2013
SHEET NO. 3 of 5



SOURCE:

FRESNO COUNTY - SOIL SURVEY OF EASTERN FRESNO AREA, CA. (USDA AND NRCS, 2008)

KINGS COUNTY - SOIL SURVEY OF KINGS COUNTY, CA. (USDA AND NRCS, 2007)

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KERN COUNTY - SOIL SURVEY OF KERN COUNTY, CA. NORTHWESTERN PART (USDA AND NRCS, 1981)

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

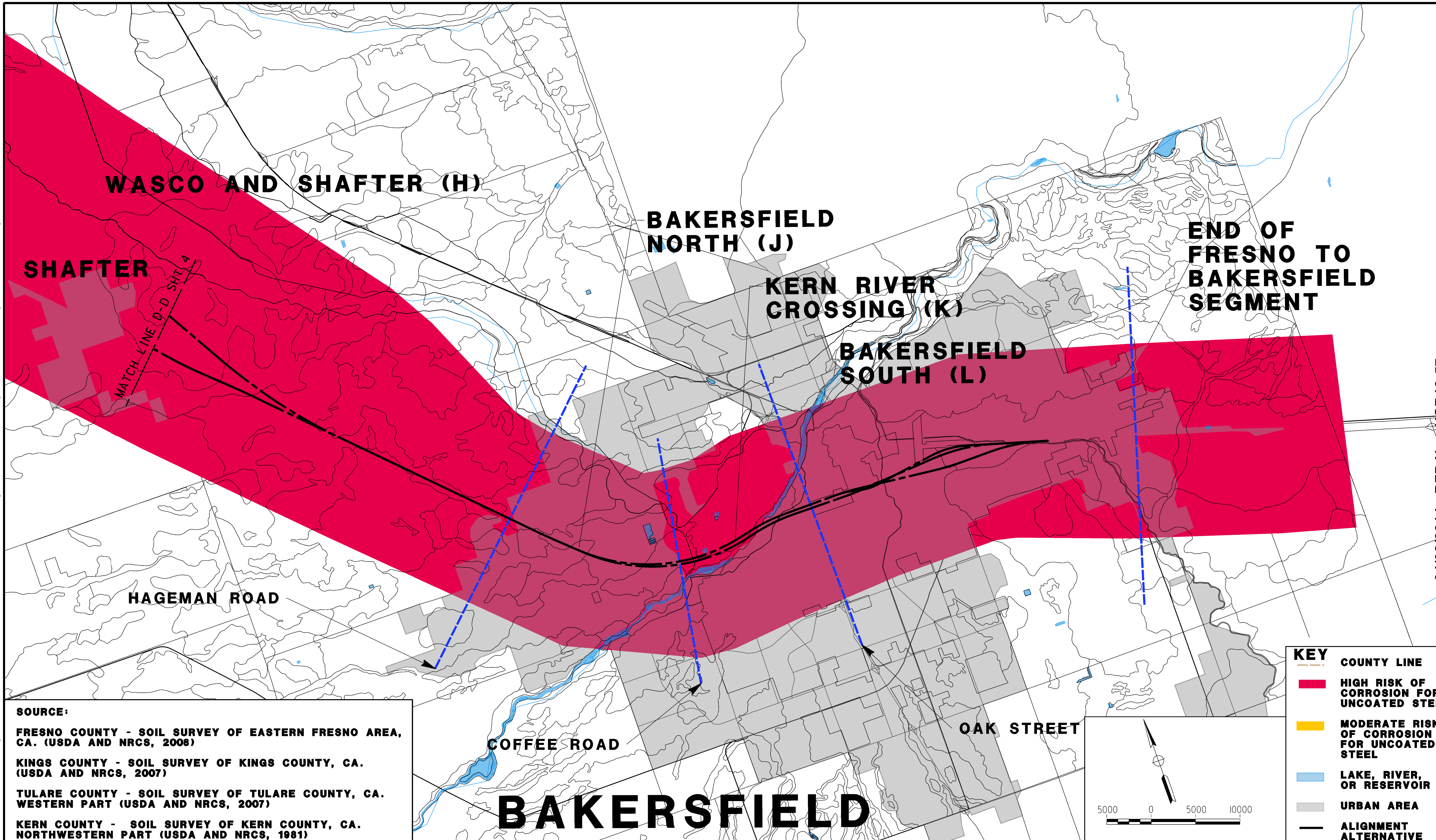
CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
SOIL CORROSIVITY-UNCOATED STEEL: FB-G to FB-H

FIGURE NO. A23d

DATE DECEMBER 2013

SHEET NO. 4 of 5



SOURCE:

FRESNO COUNTY - SOIL SURVEY OF EASTERN FRESNO AREA, CA. (USDA AND NRCS, 2008)

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KERN COUNTY - SOIL SURVEY OF KERN COUNTY, CA. NORTHWESTERN PART (USDA AND NRCS, 1981)

04/02/2014 - RFP No.: HSR13-57

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

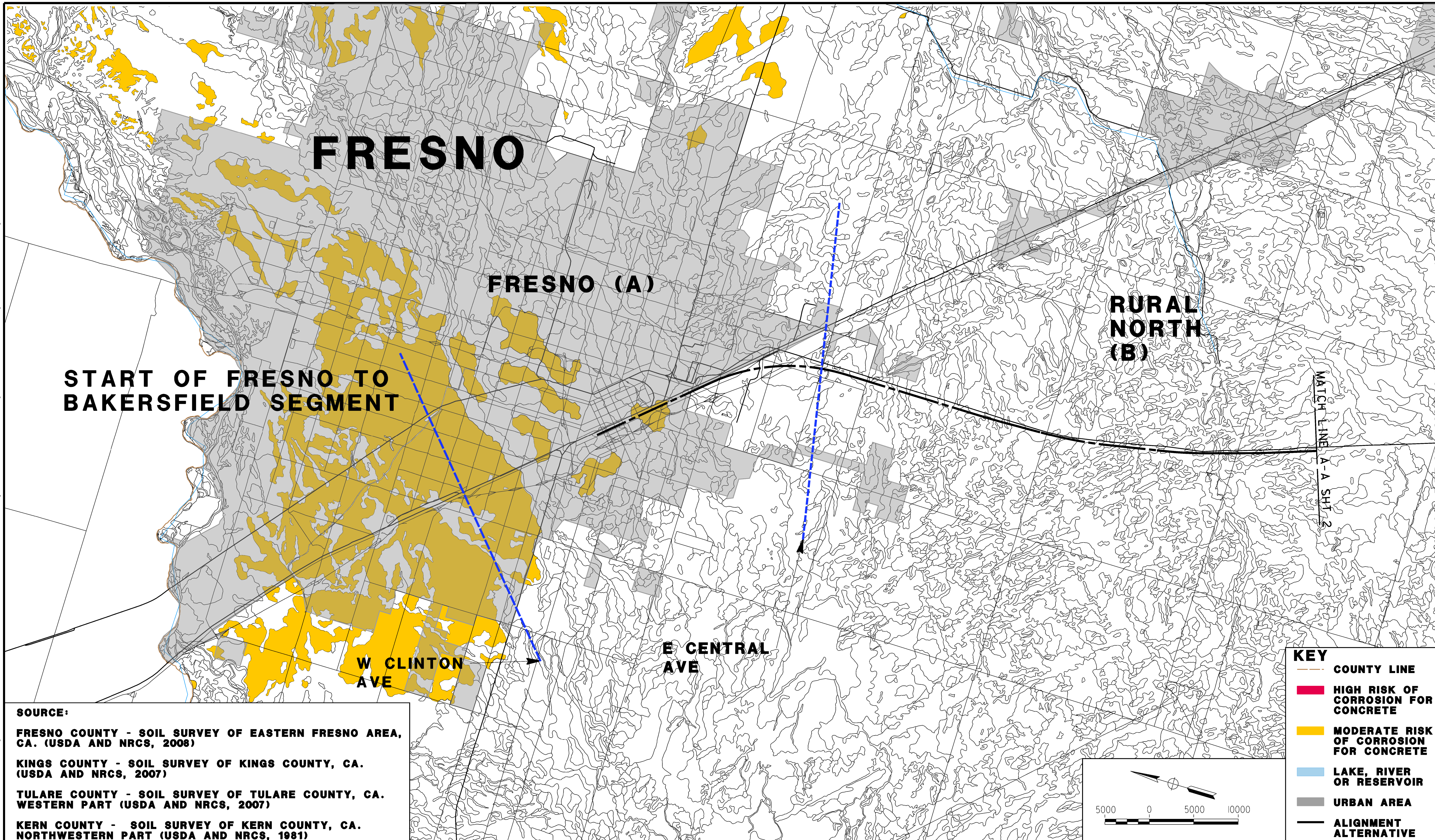
CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
SOIL CORROSIVITY-UNCOATED STEEL: FB-E to FB-G

FIGURE NO. A23e

DATE DECEMBER 2013

SHEET NO. 5 of 5

Jodi.Borghesi 12/20/2013 11:15:05 AM \\global\americas\Jobs\S-F\131000\131577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\2012-01-11_ 15% Seismic & Geologic



SOURCE:

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KERN COUNTY - SOIL SURVEY OF KERN COUNTY, CA. NORTHWESTERN PART (USDA AND NRCS, 1981)

KEY

- COUNTY LINE
- HIGH RISK OF CORROSION FOR CONCRETE
- MODERATE RISK OF CORROSION FOR CONCRETE
- LAKE, RIVER OR RESERVOIR
- URBAN AREA
- ALIGNMENT ALTERNATIVE

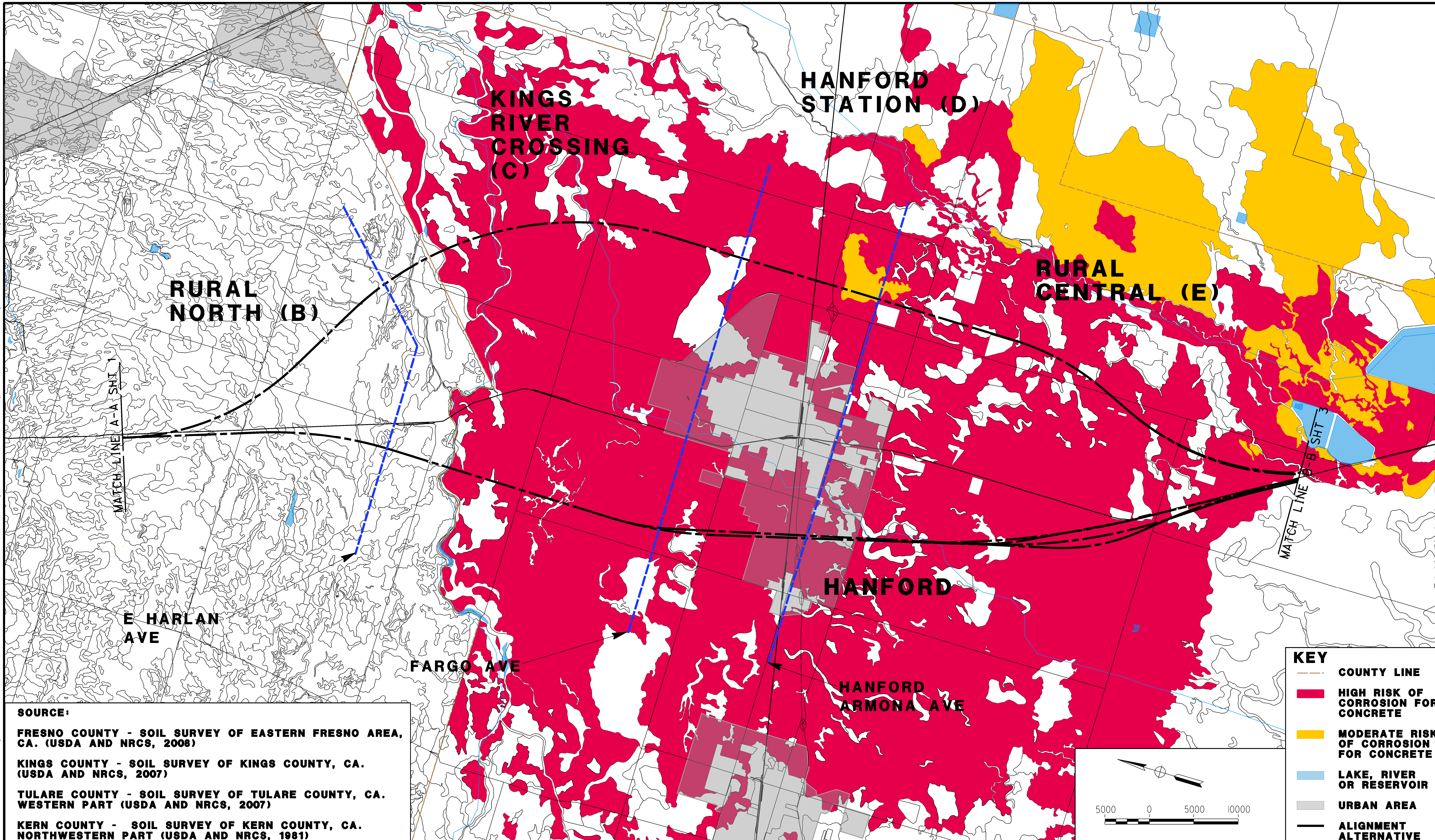
URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
SOIL CORROSIVITY-CONCRETE: FB-A to FB-B

FIGURE NO.	A24a
DATE	DECEMBER 2013
SHEET NO.	1 of 5

04/02/2014 - RFP No.: HSR13-57



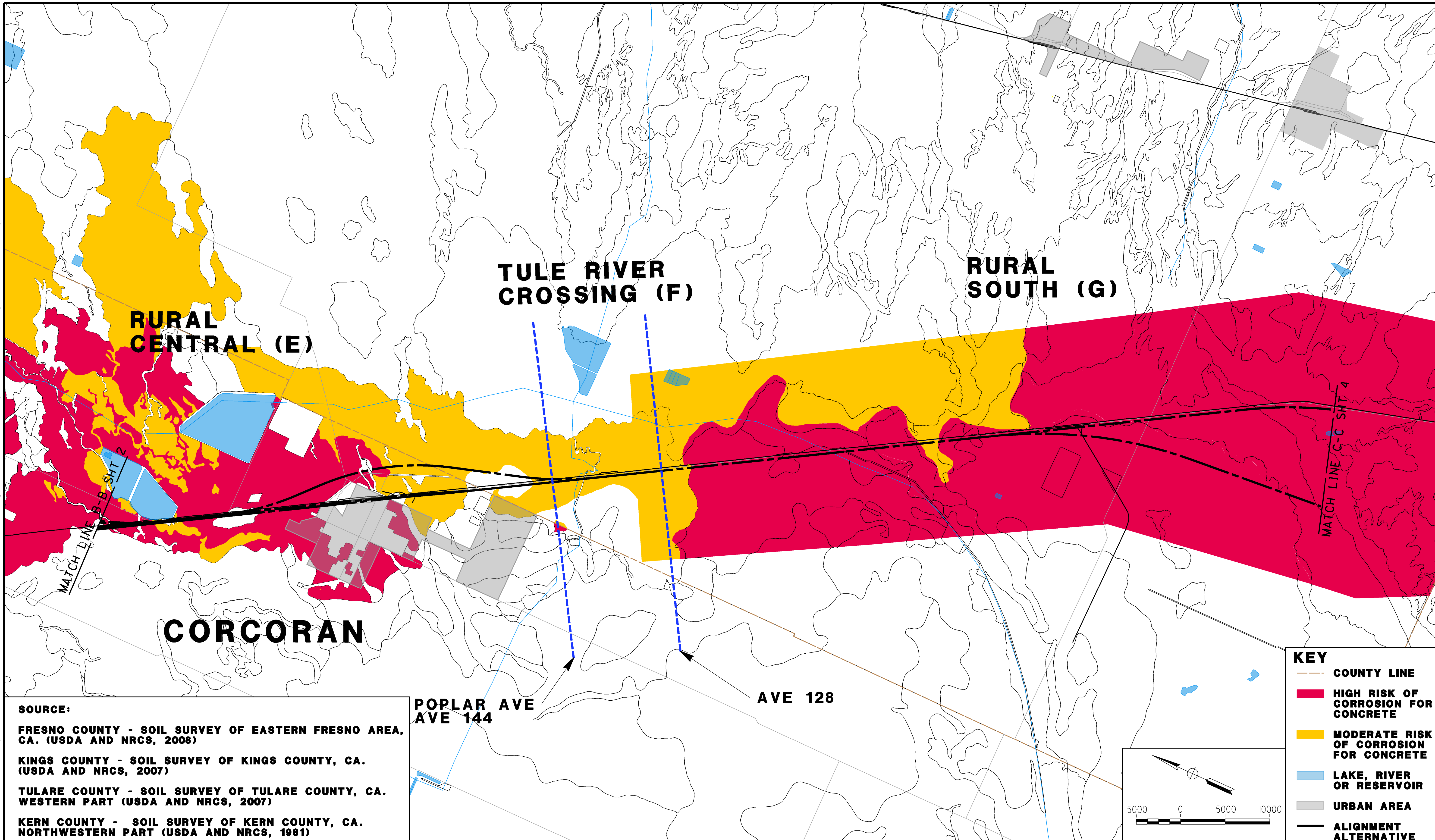
04/02/2014 - RFP No.: HSR13-57

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
SOIL CORROSIVITY-CONCRETE: FB-B to FB-E

FIGURE NO.	A24b
DATE	DECEMBER 2013
SHEET NO.	2 of 5



SOURCE:

FRESNO COUNTY - SOIL SURVEY OF EASTERN FRESNO AREA, CA. (USDA AND NRCS, 2008)

KINGS COUNTY - SOIL SURVEY OF KINGS COUNTY, CA. (USDA AND NRCS, 2007)

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KERN COUNTY - SOIL SURVEY OF KERN COUNTY, CA. NORTHWESTERN PART (USDA AND NRCS, 1981)

04/02/2014 - RFP No.: HSR13-57

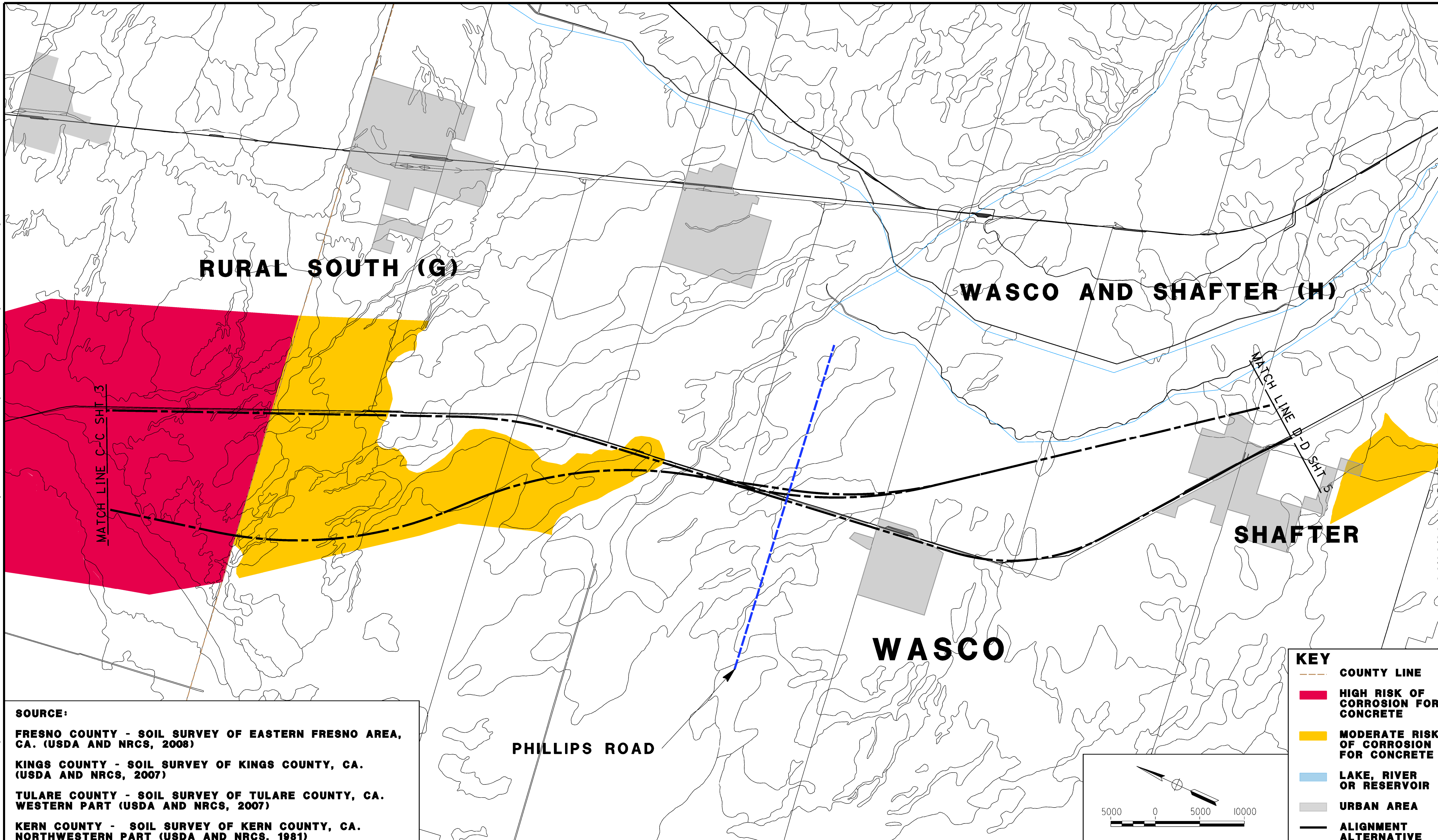
URS | HMM | ARUP CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
SOIL CORROSIVITY-CONCRETE: FB-E to FB-G

FIGURE NO.	A24c
DATE	DECEMBER 2013
SHEET NO.	3 of 5

Jodi.Borghesi 12/20/2013 12:09:02 PM \\global\americas\Jobs\S-F\131000\131577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\2012-01-11_ 15% Seismic & Geologic



SOURCE:

FRESNO COUNTY - SOIL SURVEY OF EASTERN FRESNO AREA, CA. (USDA AND NRCS, 2008)

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KERN COUNTY - SOIL SURVEY OF KERN COUNTY, CA. NORTHWESTERN PART (USDA AND NRCS, 1981)

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

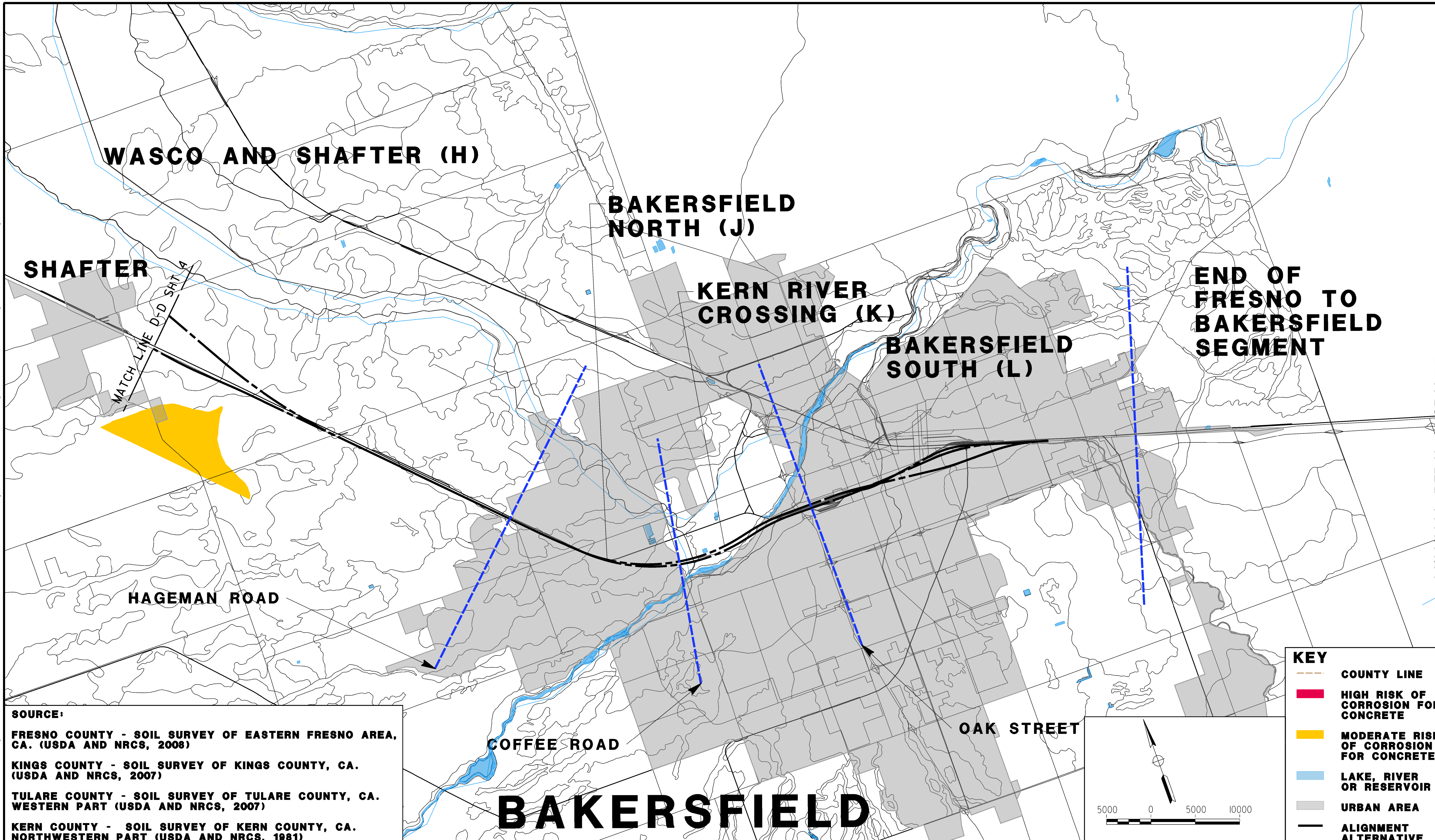
CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
SOIL CORROSIVITY-CONCRETE: FB-G to FB-H

FIGURE NO. A24d

DATE DECEMBER 2013

SHEET NO. 4 of 5

Jodi.Borghesi 12/20/2013 12:19:23 PM \\global\americas\Jobs\S-F\131000\131577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\2012-01-11_ 15% Seismic & Geologic



SOURCE:

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KERN COUNTY - SOIL SURVEY OF KERN COUNTY, CA. NORTHWESTERN PART (USDA AND NRCS, 1981)

04/02/2014 - RFP No.: HSR13-57

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

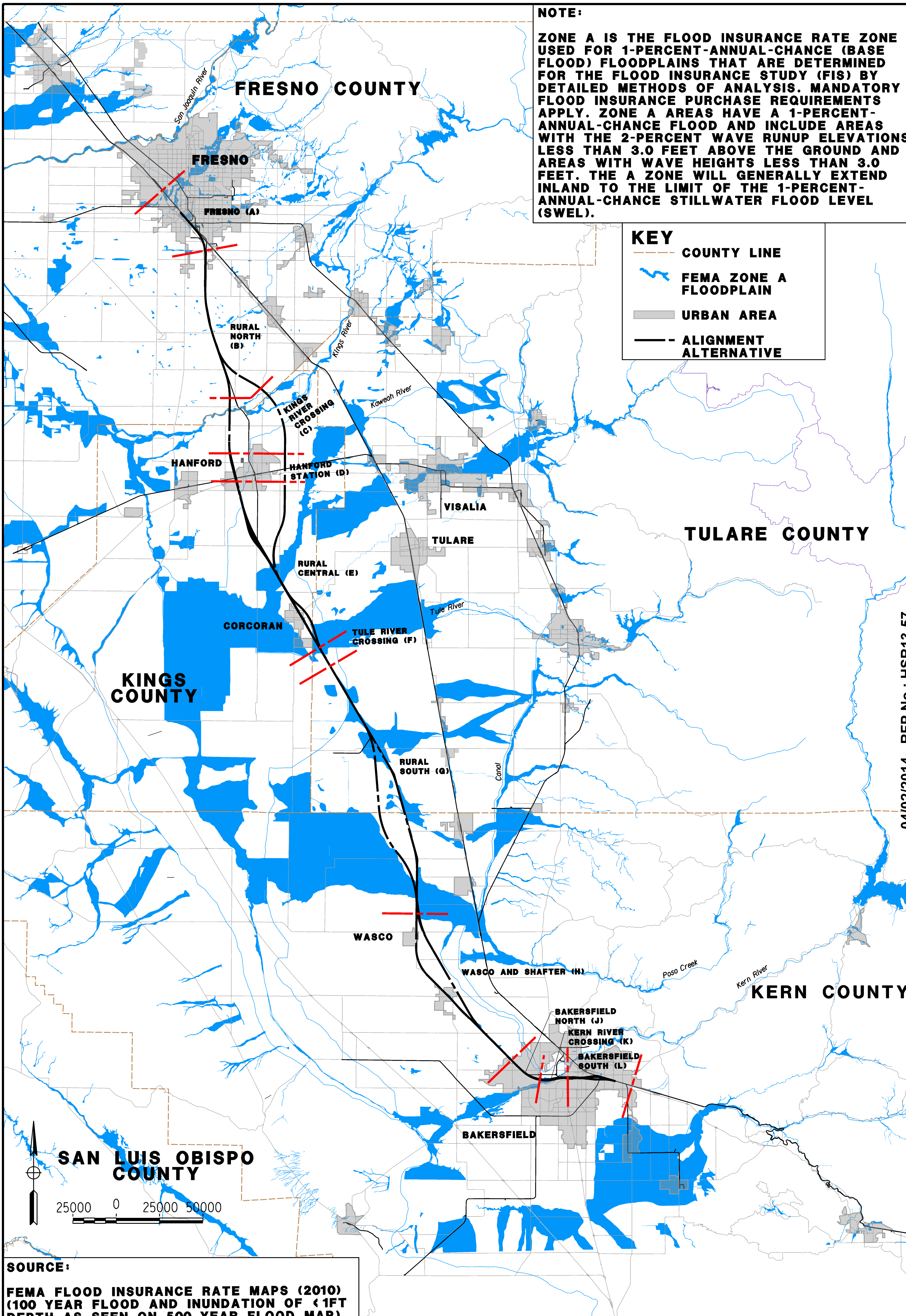
CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
SOIL CORROSIVITY-CONCRETE: FB-H to FB-L

FIGURE NO. A24e

DATE DECEMBER 2013

SHEET NO. 5 of 5



NOTE:

ZONE A IS THE FLOOD INSURANCE RATE ZONE USED FOR 1-PERCENT-ANNUAL-CHANCE (BASE FLOOD) FLOODPLAINS THAT ARE DETERMINED FOR THE FLOOD INSURANCE STUDY (FIS) BY DETAILED METHODS OF ANALYSIS. MANDATORY FLOOD INSURANCE PURCHASE REQUIREMENTS APPLY. ZONE A AREAS HAVE A 1-PERCENT-ANNUAL-CHANCE FLOOD AND INCLUDE AREAS WITH THE 2-PERCENT WAVE RUNUP ELEVATIONS LESS THAN 3.0 FEET ABOVE THE GROUND AND AREAS WITH WAVE HEIGHTS LESS THAN 3.0 FEET. THE A ZONE WILL GENERALLY EXTEND INLAND TO THE LIMIT OF THE 1-PERCENT-ANNUAL-CHANCE STILLWATER FLOOD LEVEL (SWEL).

KEY

- COUNTY LINE
- FEMA ZONE A FLOODPLAIN
- URBAN AREA
- ALIGNMENT ALTERNATIVE

04/02/2014 - RFP No.: HSR13-57

SOURCE:

FEMA FLOOD INSURANCE RATE MAPS (2010) (100 YEAR FLOOD AND INUNDATION OF <1FT DEPTH AS SEEN ON 500 YEAR FLOOD MAP)

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
FEMA ZONE A FLOODPLAIN

FIGURE NO. A25
DATE DECEMBER 2013
SHEET NO. 1 OF 1

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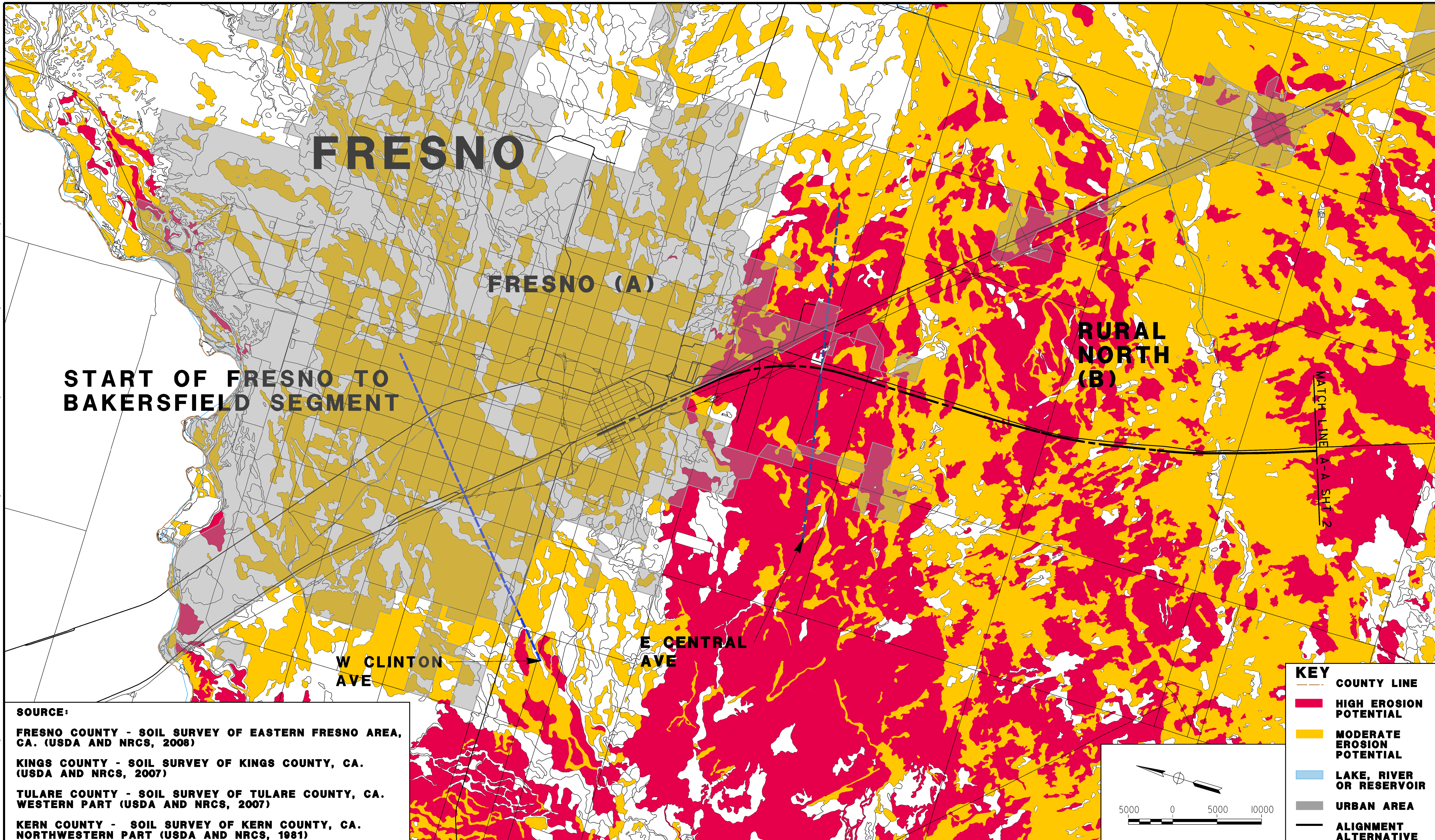

SOURCE:

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KERN COUNTY - SOIL SURVEY OF KERN COUNTY, CA. NORTHWESTERN PART (USDA AND NRCS, 1981)

04/02/2014 - RFP No.: HSR13-57

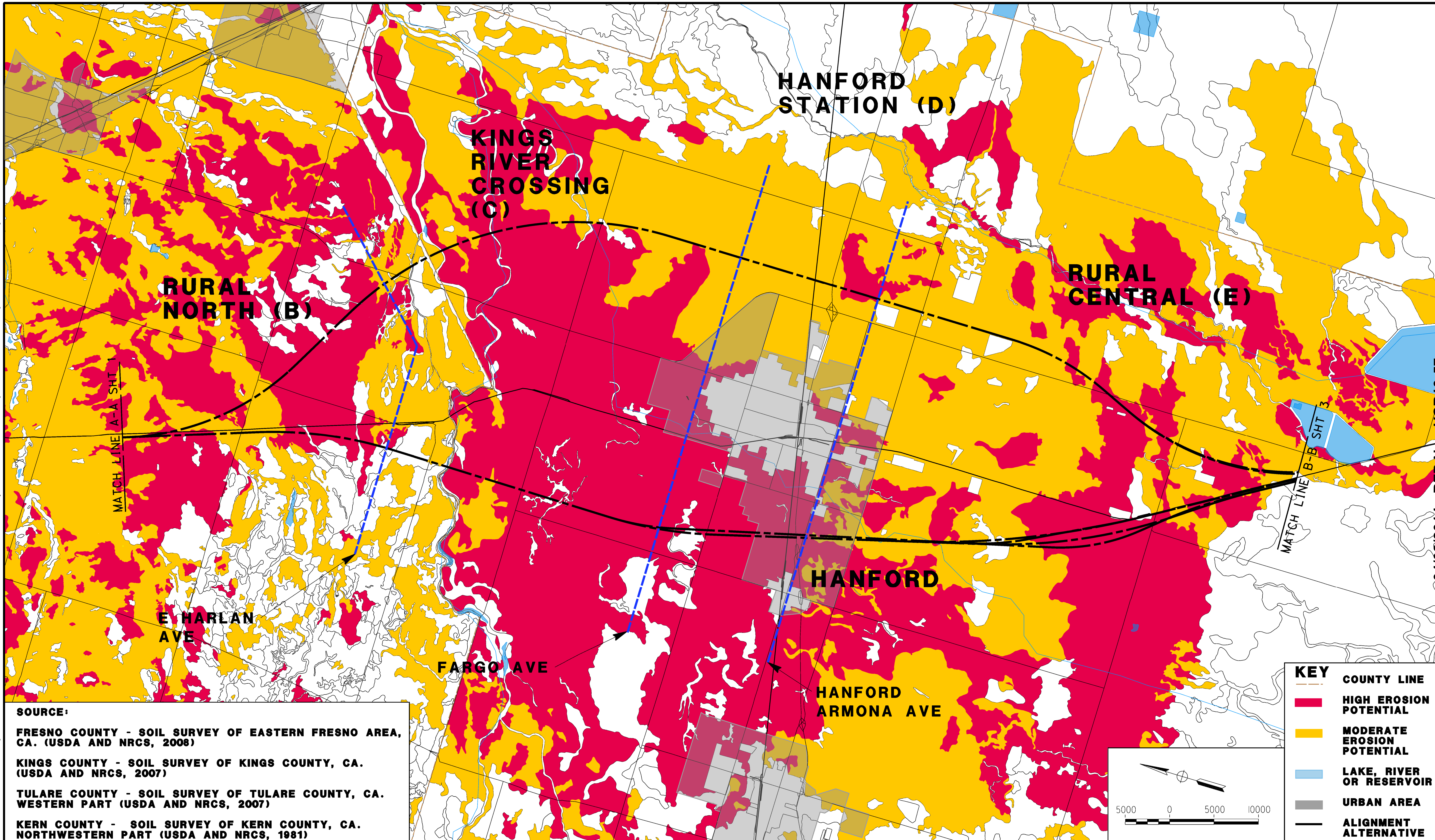
URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
ERODIBLE SOILS: FB-A to FB-B

FIGURE NO. A26a
DATE DECEMBER 2013
SHEET NO. 1 of 5

Jodi.Borghesi 12/20/2013 12:55:32 PM \\global\americas\Jobs\S-F\131000\131577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\2012-01-11_ 15% Seismic & Geologic

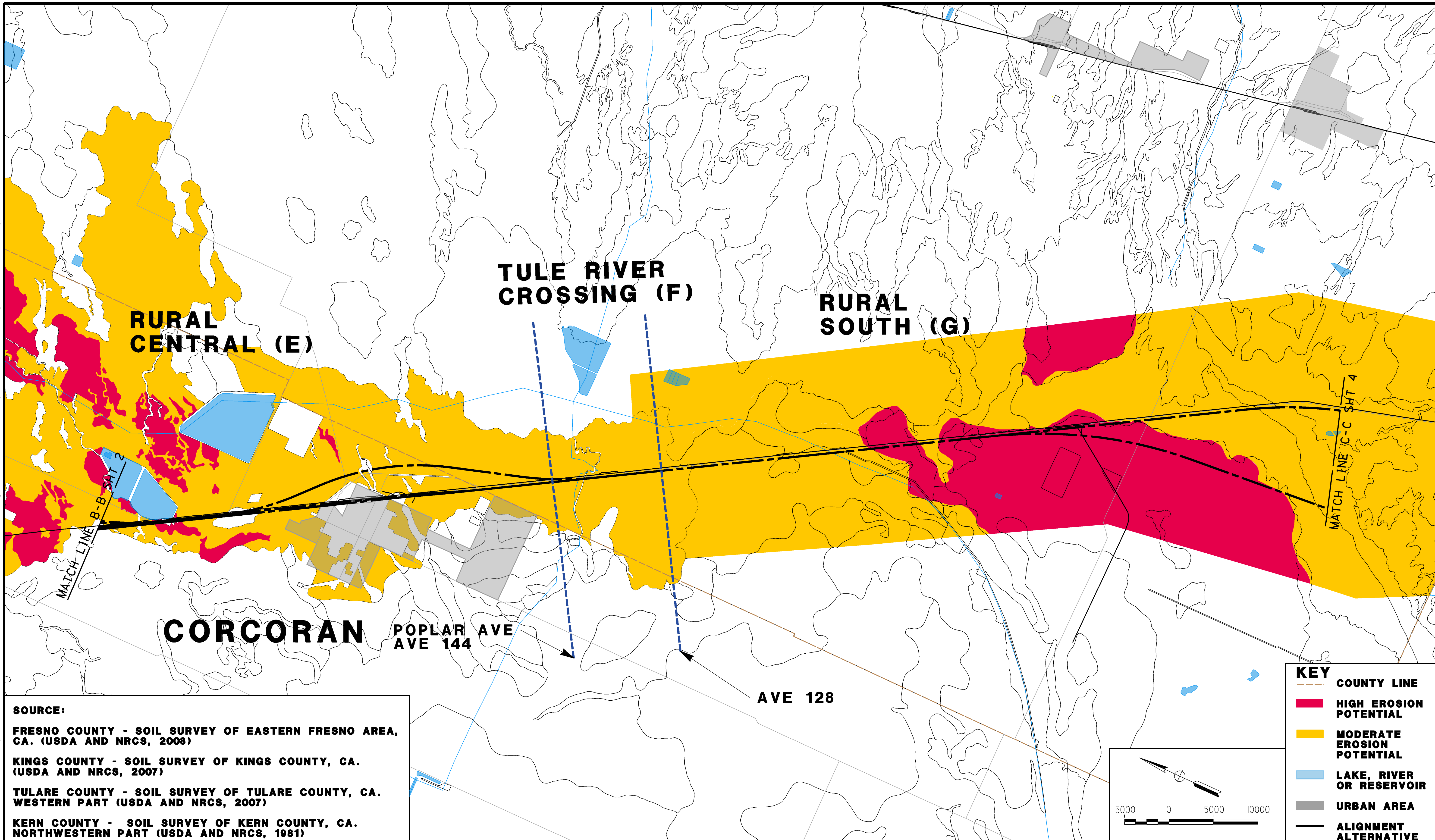


URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
ERODIBLE SOILS: FB-B to FB-E

FIGURE NO. A26b
DATE DECEMBER 2013
SHEET NO. 2 of 5



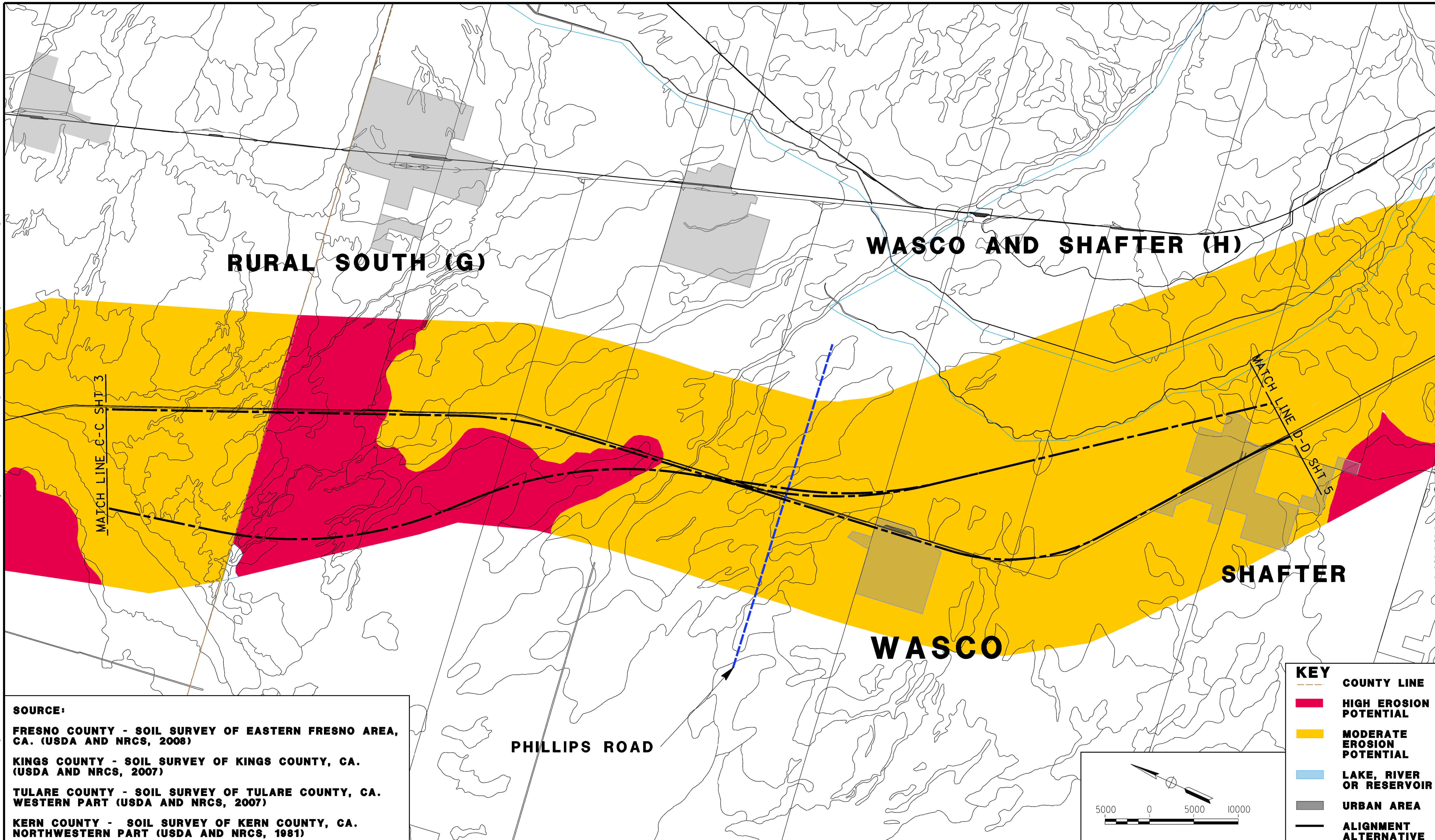
URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
ERODIBLE SOILS: FB-E to FB-G

FIGURE NO. A26c
DATE DECEMBER 2013
SHEET NO. 3 of 5

04/02/2014 - RFP No.: HSR13-57



SOURCE:

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KERN COUNTY - SOIL SURVEY OF KERN COUNTY, CA. NORTHWESTERN PART (USDA AND NRCS, 1981)

04/02/2014 - RFP No.: HSR13-57

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

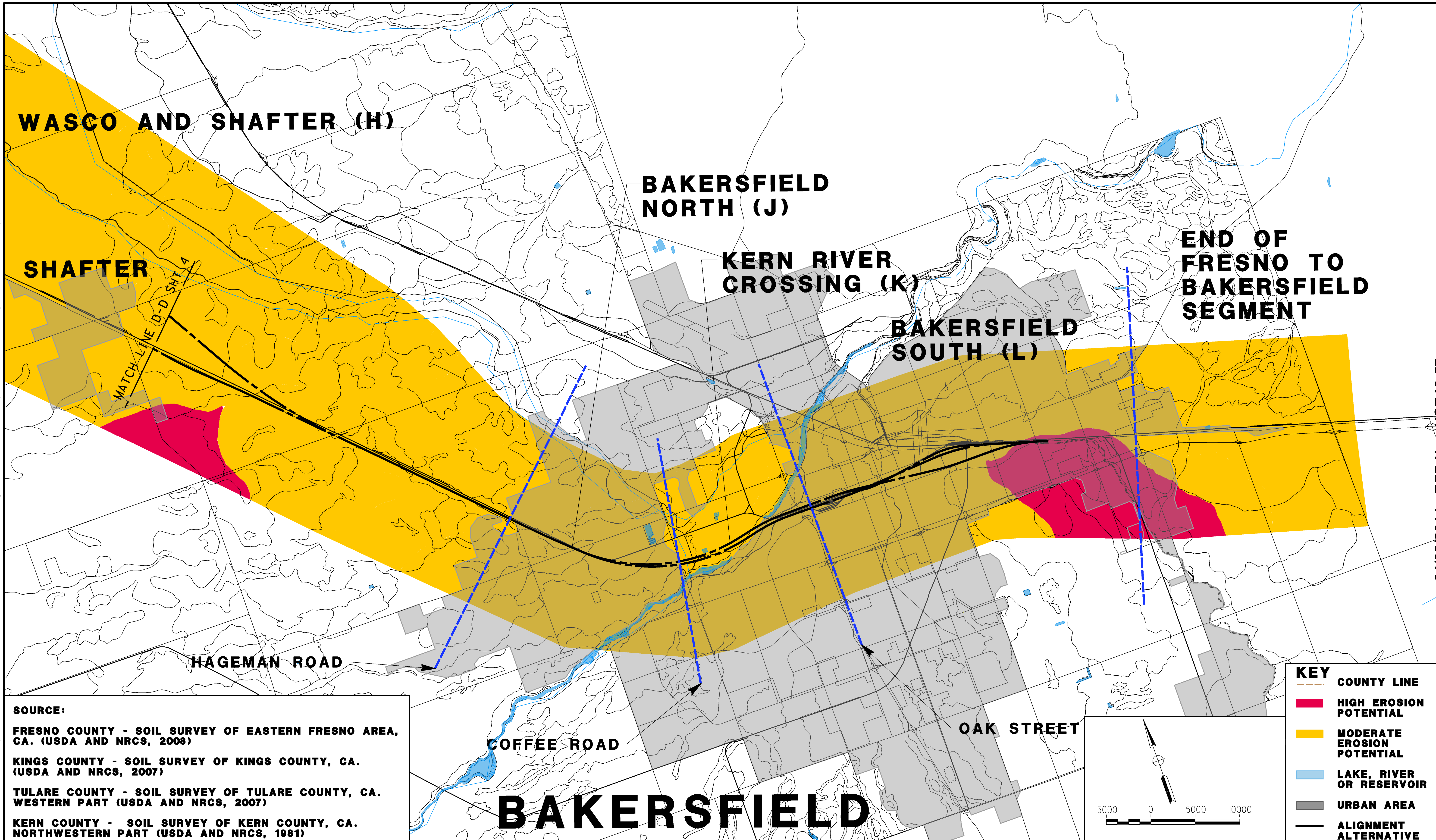
CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
ERODIBLE SOILS: FB-G to FB-H

FIGURE NO. A26d

DATE DECEMBER 2013

SHEET NO. 4 of 5

Jodi.Borghesi 12/20/2013 1:09:03 PM \\global\americas\Jobs\S-F\131000\131577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\2012-01-11_ 15% Seismic & Geologic



SOURCE:

FRESNO COUNTY - SOIL SURVEY OF EASTERN FRESNO AREA, CA. (USDA AND NRCS, 2006)

KINGS COUNTY - SOIL SURVEY OF KINGS COUNTY, CA. (USDA AND NRCS, 2007)

TULARE COUNTY - SOIL SURVEY OF TULARE COUNTY, CA. WESTERN PART (USDA AND NRCS, 2007)

KERN COUNTY - SOIL SURVEY OF KERN COUNTY, CA. NORTHWESTERN PART (USDA AND NRCS, 1981)

04/02/2014 - RFP No.: HSR13-57

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
ERODIBLE SOILS: FB-H to FB-L

FIGURE NO.	A26e
DATE	DECEMBER 2013
SHEET NO.	5 of 5

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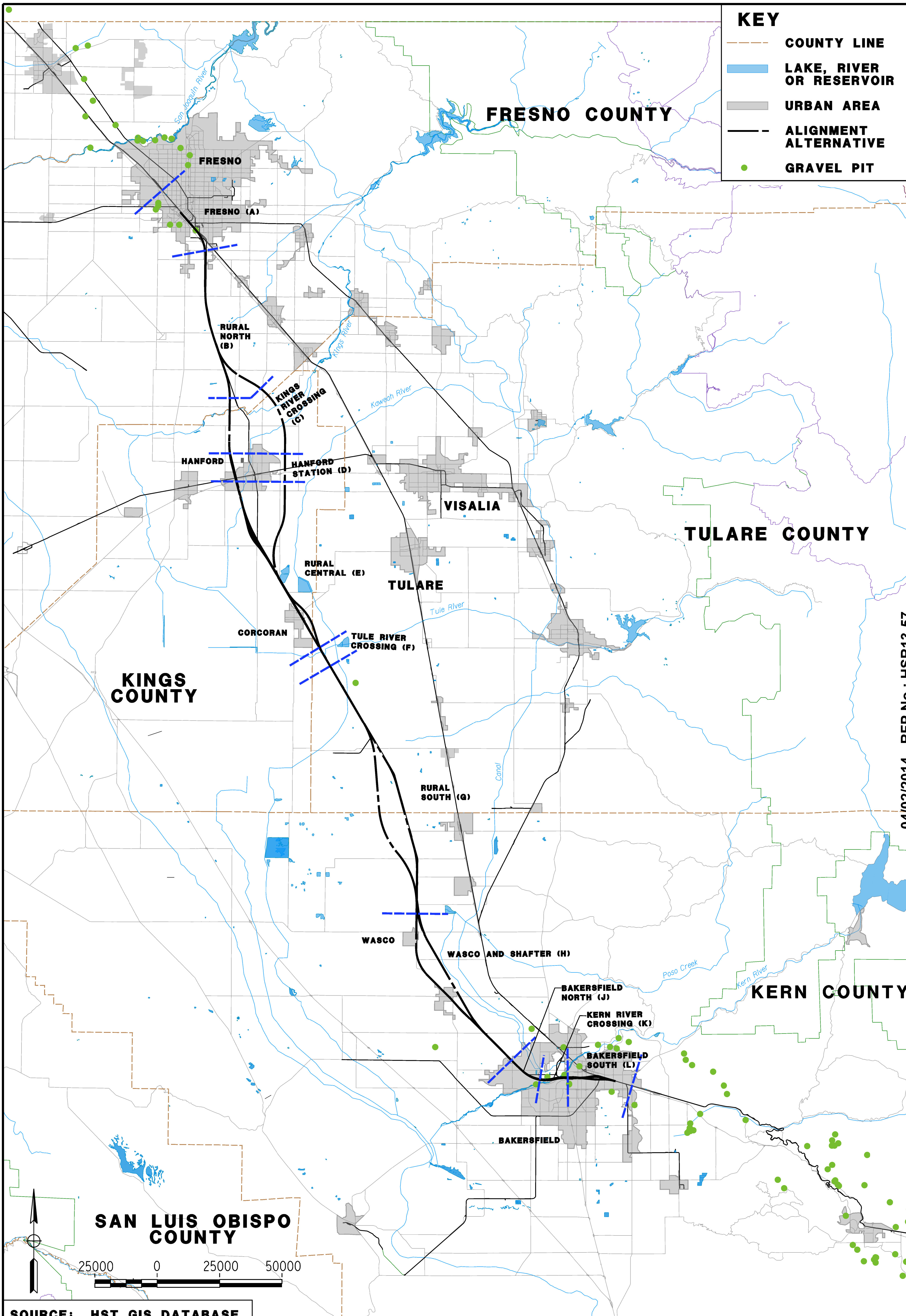

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD

GRAVEL PITS

FIGURE NO.	A27
DATE	DECEMBER 2013
SHEET NO.	1 OF 1

\\global\americas\Jobs\S-F\31000\31577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\2012-01-11_ 15% Seismic & Geological Hazards\FB-GB-6026.dgn
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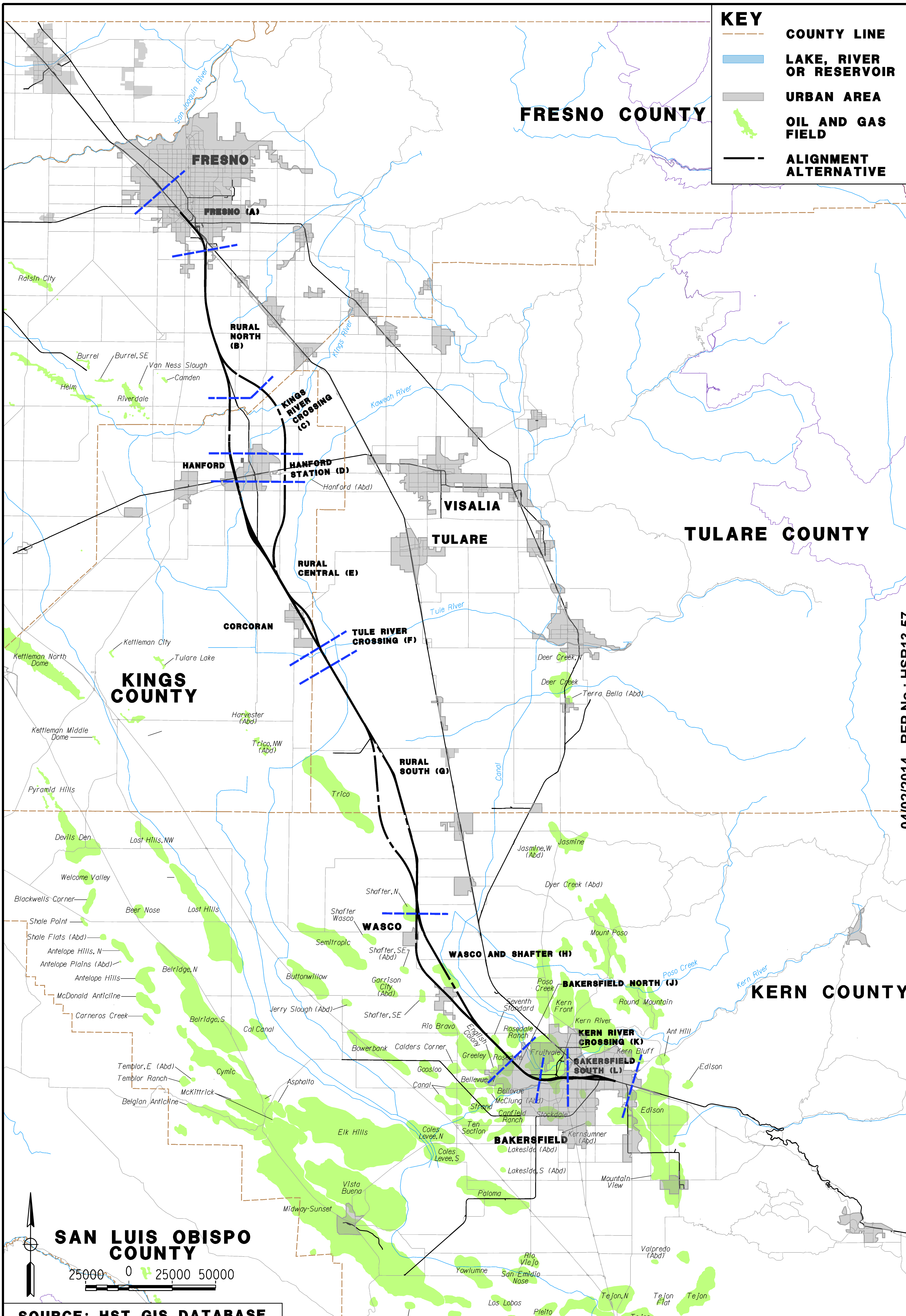

04/02/2014 - RFP No.: HSR13-57

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
OIL AND GAS FIELDS

FIGURE NO.	A28
DATE	DECEMBER 2013
SHEET NO.	1 OF 1

\\global\americas\Jobs\S-F\31000\31577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\2012-01-11_ 15% Seismic & Geological Hazards\FB-GB-6027.dgn
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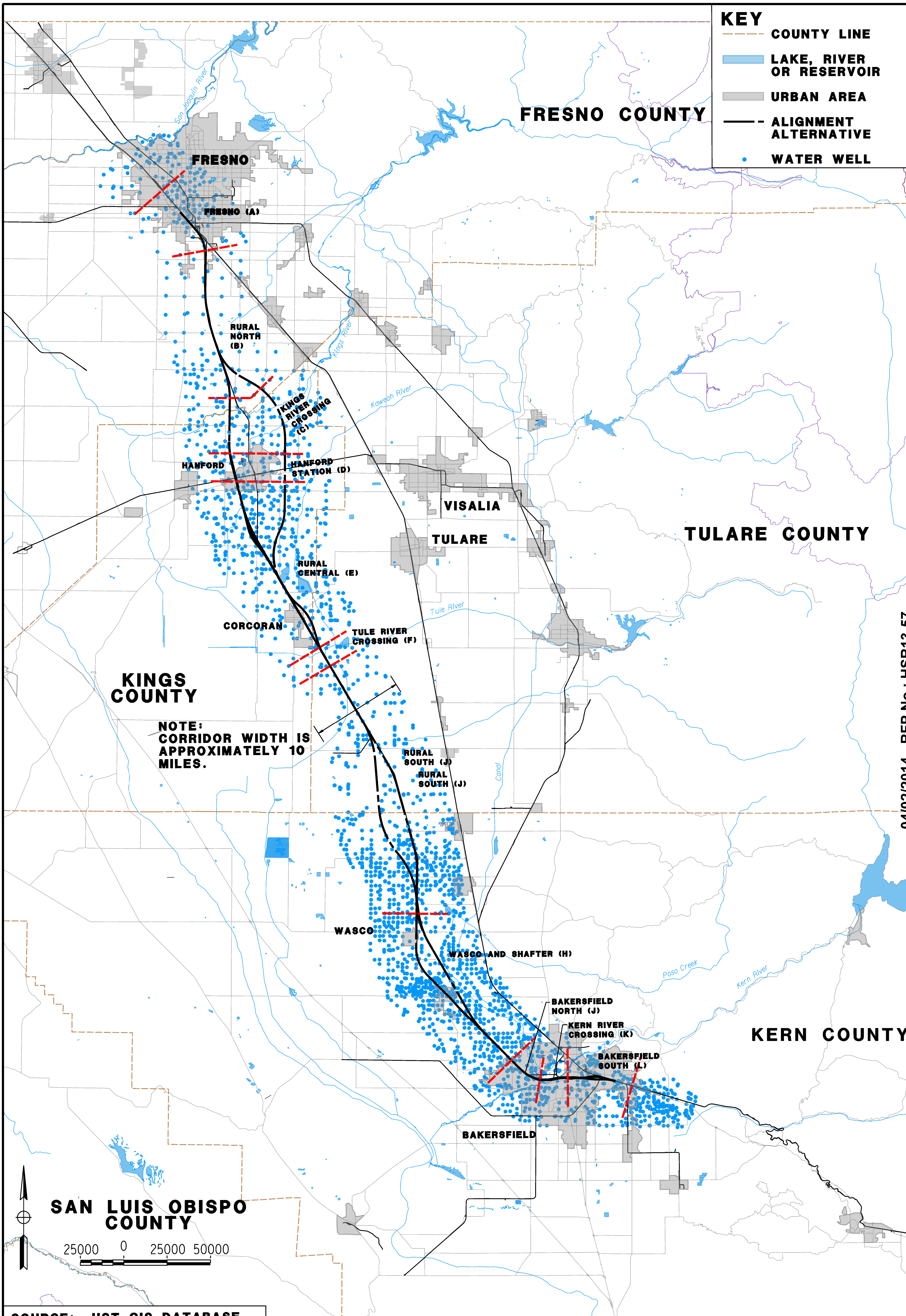

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
WATER WELLS

FIGURE NO.	A29
DATE	DECEMBER 2013
SHEET NO.	1 OF 1

\\global\americas\Jobs\S-F\31000\31577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\2012-01-11_ 15% Seismic & Geological Hazards\FB-GB-6028.dgn
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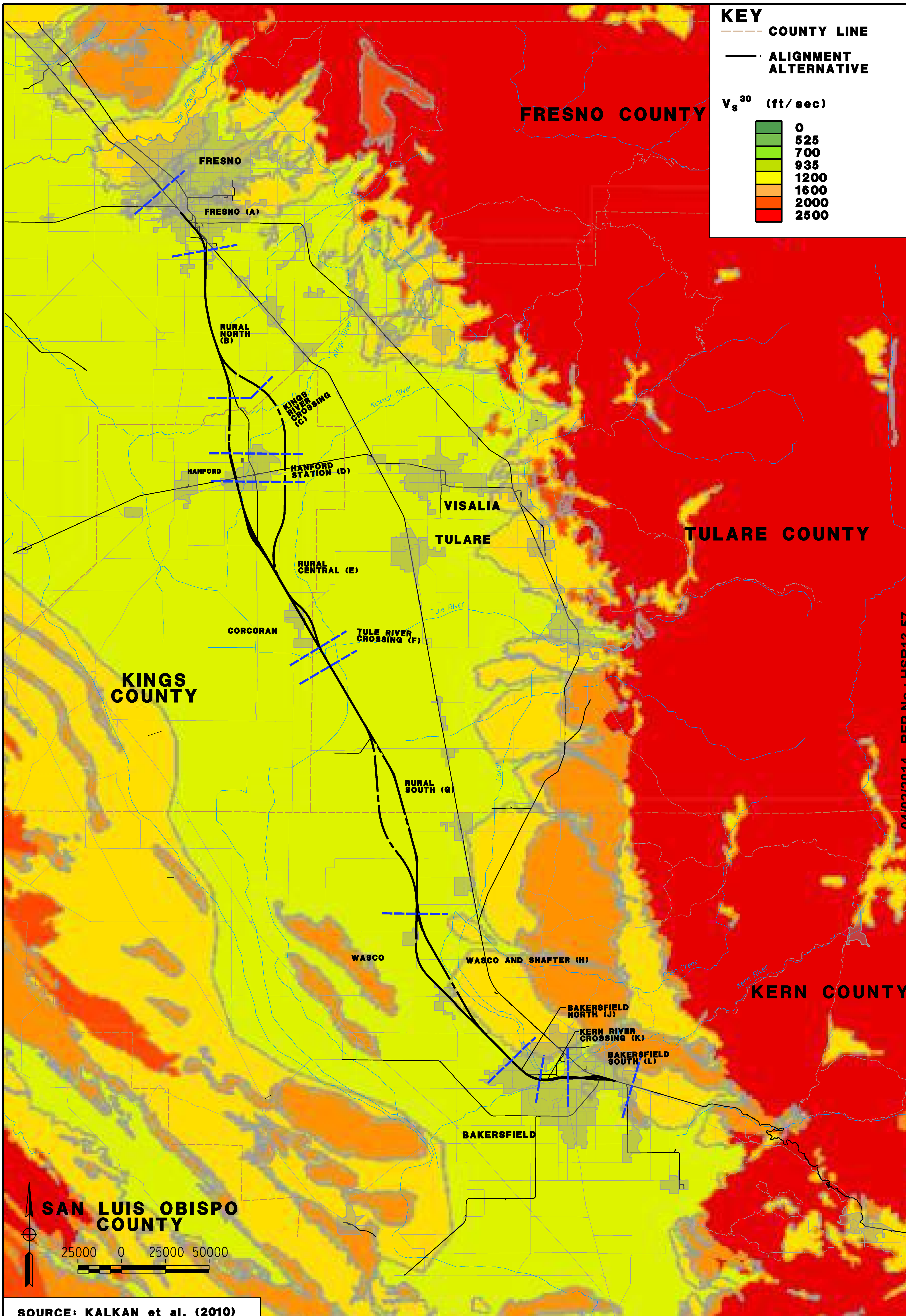

04/02/2014 - RFP No.: HSR13-57

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
SHEAR WAVE VELOCITY OF UPPER 100 FEET (V_S^{30})

FIGURE NO.	A30
DATE	DECEMBER 2013
SHEET NO.	1 OF 1

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Appendix B

Preliminary Aerial Photography and Map Review

Table of Contents

Figures

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1.0 Introduction

1.1 Scope of Work

This appendix provides the results of the preliminary aerial photography interpretation and map review conducted for the Fresno-to-Bakersfield HST corridor. This study considered the most recent alignment alternatives including Hanford West Bypass alternative.

The primary deliverable for the aerial photography interpretation is a GIS file detailing the georeferenced location of defined categories of features (see Section 2.1 below) with an associated 'tag' briefly describing the feature. This summary presents an overview of the aerial photographs provided and findings of the interpretation and should be read in conjunction with Figures B1 to B7 and the GIS file stored in the project GIS database and the body of the Fresno to Bakersfield Geologic and Seismic Hazard Report dated May 2012.

1.2 Aerial Photographs

The historical aerial photographs were provided to the URS/HMM/Arup Joint Venture (JV) from the counties the Fresno to Bakersfield segment of the CHSTP passes through; from north to south; Fresno, Kings, Tulare and Kern Counties. The aerial photographs provided were vertical, monochrome mosaics.

The aerial photographs from the following counties and years were assessed as part of the study;

- Fresno County: 1937, 1950, 1957, 1961, 1965, 1967, 1973, and 1977,
- Kings County: 1937, 1940, 1942, 1957, and 1961,
- Tulare County: 1937, 1956, 1961, and 1967,
- Kern County: 1937, 1952, 1956, and 1958.

The historical aerial photographs provided for each year do not cover the full alignment or necessarily even cover the county to which they pertain. Figures B2a to B2m show the distribution by date of the aerial photography used in this interpretation. In addition to the historical aerial photographs provided by the counties the latest Microsoft Bing and Google Earth aerial photographs were assessed to provide a recent perspective. Google Earth provides useable satellite imagery for the study area dating back to 1994.

1.3 Maps

Various map sources were reviewed to cross reference and verify, to the extent practical, features identified and cataloged in the Aerial Photography Interpretation database. The following sources were reviewed.

California geologic maps covering the entire alignment available at http://www.gelib.com/california-geologic-maps.htm on-line as Google Earth overlays were reviewed including:

- Jenkins, O.P. 1964. Geological Map of California Bakersfield Sheet, Division of Mines and Geology
- Jenkins, O.P. 1965. Geological Map of California Fresno Sheet, Division of Mines and Geology
- Page, R.W. 1986. Geology of the fresh ground-water basin of the Central Valley, California, with texture maps and sections: United States Geological Survey, Professional Paper 1401-C.

USGS Topographic maps covering the entire alignment available at http://www.gelib.com/usgs-topographic-maps-2.htm on-line as Google Earth overlays were reviewed including:

- (1992), Lamont, CA Quadrangle, 7.5 Minute Series
- (1954), Gosford, CA Quadrangle, 7.5 Minute Series, Photorevised 1968 and 1973
- (1954), Rosedale, CA Quadrangle, 7.5 Minute Series, Photorevised 1968 and 1973
- (1954), Wasco, CA Quadrangle, 7.5 Minute Series, Photorevised 1968 and 1973
- (1954), Rio Bravo, CA Quadrangle, 7.5 Minute Series, Photorevised 1968 and 1973
- (1954), Famosa, CA Quadrangle, 7.5 Minute Series, Photorevised 1968
- (1954), Pond CA Quadrangle, 7.5 Minute Series, Photorevised 1969 and 1973
- (1954), Delano West, CA Quadrangle, 7.5 Minute Series, Photorevised 1969
- (1954), Alpaugh, CA Quadrangle, 7.5 Minute Series, Photorevised 1969
- (1954), Allensworth, CA Quadrangle, 7.5 Minute Series, Photorevised 1969
- (1954), Pixley, CA Quadrangle, 7.5 Minute Series, Photorevised 1969
- (1950), Taylor Weir, CA Quadrangle, 7.5 Minute Series, Photorevised 1969
- (1954), Corcoran, CA Quadrangle, 7.5 Minute Series
- (1954), Wuakena, CA Quadrangle, 7.5 Minute Series
- (1954), Remnoy, CA Quadrangle, 7.5 Minute Series
- (1954), Burris Park, CA Quadrangle, 7.5 Minute Series
- (1954), Guernsey, CA Quadrangle, 7.5 Minute Series
- (1954), Hanford, CA Quadrangle, 7.5 Minute Series
- (1963), Cojeno, CA Quadrangle, 7.5 Minute Series, Photorevised 1978
- (1964), Malaga, CA Quadrangle, 7.5 Minute Series, Photorevised 1981
- (1963), Fresno South, CA Quadrangle, 7.5 Minute Series, Photorevised 1981
- (1965), Fresno North, CA Quadrangle, 7.5 Minute Series, Photorevised 1981

Historic USGS Topographic maps covering limited sections of the alignment available at http://www.gelib.com/historic-topographic-maps.htm on-line as Google Earth overlays were reviewed including:

- (1929), Allensworth, CA Quadrangle, 7.5 Minute Series
- (1929), Alpaugh, CA Quadrangle, 7.5 Minute Series
- (1928), Corcoran, CA Quadrangle, 7.5 Minute Series
- (1954), Burris Park, CA Quadrangle, 7.5 Minute Series

Other Google Earth overlay map sources evaluated in this study include:

- National Geographic topo maps available on-line at http://www.gelib.com/ng-topo.htm
- Google Maps available on-line at http://www.gelib.com/google-maps.htm

2.0 Aerial Photography Interpretation

2.1 Interpretation Procedure

The aerial photographs provided by the counties were digitized, georeferenced and stored as part of the project GIS system by the JV. These digitized electronic files were then viewed by county and by year as layers in GIS for this study. The following general procedure was used to assess the historical aerial photographs:

- A GIS file was created that showed the current alignment and a one mile buffer on each side of the alignment.

- The aerial photographs were then inserted with each year representing a layer.

- The screen scale was set to 1:12,000 and the aerial photographs were reviewed by year starting with the oldest (1937).
- After each year's photographs were scrutinized, the next year was overlain and compared with the previous year to assess changes before the more recent year's photograph's features were assessed by themselves. This procedure was repeated finishing with an assessment of the latest Microsoft Bing and Google Earth Pro aerial photographs.
- Features identified were marked and saved as a layer within the GIS system. The features were also 'tagged' with the following information; unique feature identification number, feature type, year feature was first identified, year feature was last seen, and a brief description of the feature. This information is contained in the GIS file.
- Features were compared against compilations of USGS 7.5 minute quadrangle topographic maps, geologic maps (Jenkins 1964 and 1965) and other maps available as Google Earth overlays dating back to 1929 along the alignment.
- Significant features identified in the map review not identified in the Aerial Photography Interpretation were incorporated into the GIS database.

2.2 Definitions of Features

The following classifications were used to describe the features and are shown on Figure B3 through B7:

- Geological – natural features such as old in-filled river channels, salt affected soils etc.;
- Hydrological – features associated with water, natural or manmade, including rivers, streams, ponds, reservoirs, drainage ditches, and canals etc.;
- Man-made – man-made features including large road crossings, railroad crossing, large buildings, and gravel pits etc.;
- Large scale – regional features such as dune fields, river valleys, historic lake beds etc.;
- Urban areas; and
- Miscellaneous – any other feature not fitting into the above classification.

2.3 Terrain Units

The assessment divided the alignment into the following five terrain units with similar geology, land-use and drainage characteristics;

- **Fresno** – extends from the northern limit of the segment at West Clinton Avenue to the outskirts of Fresno at East Central Avenue and is approximately 8.5 miles in length;
- **Kings River** – extends from the outskirts of Fresno at East Central Avenue to Kansas Avenue just north of Corcoran and is approximately 36 miles in length;
- **Tulare Lake Bed** – extends from Kansas Avenue just north of Corcoran to the Colonel Allensworth State Historic Park and is approximately 23 miles in length;
- **Wasco** – extends from Colonel Allensworth State Historic Park to Fresno Avenue just north of Shafter and is approximately 24.5 miles in length;

- **Bakersfield** – extends from Fresno Avenue just north of Shafter to the southern limit of the segment at Oswell Street and is approximately 24.5 miles in length.

The location and extent of these terrain units are described in more detail in the Section 3.0 and are shown on Figures B3 to B7.

2.4 Recognition Elements

Aerial photography interpretation is based on a photographic recording of landscape features at a specific time and at a specific location. The following briefly discusses the elements used to identify features and objects in the photographs and the order of their significance to the interpretation.

The photographic interpretation begins with observation, identification and when necessary, measurement of features on a photograph. The most obvious interpretation is that of the shapes or landforms present and is one of the "first order" features assessed. The geomorphic expression of surface features along with other first order identifiers, such as hydrology and land use, can go a long way toward establishing the nature of the terrain being analyzed and alert the observer to the other more subtle "second order" features associated with such terrains (Ray 1962).

Most, if not all, identified landform features were identified using "recognition elements". The primary recognition elements are:

- **Tone:** Tone is the measure of the relative amount of light reflected and is probably the most important recognition element in monochrome photographic interpretation. Tone thus is affected by the time of day and year the photograph was taken along with local weather and atmospheric conditions as well as equipment used.

- **Color:** The human eye can distinguish about one thousand times more tints and shades of color than it can of gray making color probably the most important recognition element in photographic interpretation. However all the historical aerial photographs we received were monochromes and color is only applicable to the Microsoft Bing and Google Earth Pro aerial photography.

- **Texture:** Texture refers to the frequency of changes in tone within a defined area and, as such, depends on the scale; from small features to entire photographic frames. As such the scale of the aerial photography can have a significant effect on the any textures present. [After Ref 1]

- **Pattern:** Pattern "refers to the orderly spatial arrangement of features" (Ray 1962) . These features can be singular or multiple geologic, geomorphologic, topographic, vegetation, biogenic, or anthropogenic features and can be in two or three dimensions.

- **Shape:** Shape is the description of the feature in terms of its relief or topographic expression and is often only possible when the above recognition elements have been employed to define the feature. Shadows can be very useful in defining shapes as they can provide profile views of features that can used for identification of features (Ray 1962).

- **Size:** This quantitative element relates to the dimensions of a feature and can be useful in classifying the significance of features such as size of river crossings. Again, the scale of the aerial photography being interpreted will determine the size of the feature identifiable in the aerial photography.

These recognition elements have been used in combination or alone to identify and describe the features discussed below.

3.0 Summary of Aerial Photography Interpretation

The primary deliverable of the Aerial Photography Interpretation is the GIS file showing the location of features identified as potential geohazards and constraints with an associated 'tag' briefly describing the feature. This chapter briefly summarizes the main findings of the interpretation. The following discussion should be cross- referenced against Figures B1 to B7 and the GIS file stored in the project GIS database. For a complete description of the CAHST alignments discussed below refer to the Section 2.5 and 2.6 body of this report

3.1 Fresno: West Clinton Avenue to East Central Avenue

This area of study extends from the northern limit of the segment at West Clinton Avenue to the southern outskirts of Fresno at East Central Avenue and is approximately 8.5 miles in length. The proposed alignment runs parallel to the existing northwest-southeast running Union Pacific railroad through the center of Fresno before crossing the railroad at the south eastern part of Fresno and heading south into the rural area.

The topography of the site indicates gently undulating low relief terrain at an elevation of between 289 feet and 295 feet ASL. The gradients of the natural slopes are generally shallow and stable. Man-made slopes are assumed to be stable.

The land is generally set to urban uses such as commercial, light industrial and residential with associated infrastructure such as local roads, interstate roads and railroads as well as utilities including power and telecommunication transmission lines and water, fuel and sewer pipes. Urban infrastructure is both beneath and above the ground. There is no significant vegetation.

A number of rivers and streams emanating from the Sierra Nevada to the east pass through the area. Most of these water courses are now carried in culverts through the urban areas but are still likely to be capable of causing floods during or after high precipitation events in their watersheds. There are a number of small reservoirs and dams up slope of the alignment in this section. These reservoirs and dams could cause flooding should they be breached. In addition there are a number of small ponds or reservoirs adjacent to the proposed alignment that may pose constraints to the project.

The geologic map of the Fresno area shows the site is underlain by Pleistocene nonmarine deposits (Q_c) and Recent Great Valley fan deposits (Q_f). These deposits are likely to be of fluvial origin and be composed of gravels, sands, silts and clays with subordinate units of hard pan and organic soils. These soils combined with the possibility of elevated water tables associated with rivers increase the potential for liquefaction hazards.

Due to the low relief topography there were no significant areas of man-made cut or fill recorded. However, new areas of man-made cut or fill could have been developed since the last aerial photographs were taken.

Potential sources of aggregates are not identified within this section but could exist.

In summary, the primary potential geohazards or constraints associated with this section are existing buildings and infrastructure, unknown soil conditions (near surface and at depth) and the potential for flooding.

04/02/2014 - RFP No.: HSR13-57

3.2 Kings River: East Central Avenue, Fresno to Kansas Avenue, Corcoran

This study area extends from the outskirts of Fresno at East Central Avenue to Kansas Avenue just north of Corcoran through rural land and is approximately 36 miles in length. Two route options are being considered to bypass the town of Hanford, one located to the east, the other located to the west.

The eastern alignment option runs parallel to the existing north-south running Burlington Northern Santa Fe (BNSF) railroad before diverging in the vicinity of Conejo to bypass Hanford to the east and coalescing with the railroad and the western alignment again north of Corcoran about 4 miles south of Kansas Avenue. The Hanford West Bypass would follow the same alignment as the eastern alignment on the western side of the BNSF Railway but would trend to west immediately south of Conejo Avenue bypassing both Laton and Hanford to the west. The western bypass route would reconnect with eastern alignment about 4 miles south of Kansas Avenue.

The topography of the site indicates gently undulating low relief terrain at an elevation of between 215 feet and 295 feet ASL. The gradients of the natural slopes are generally shallow and stable with the exception of localized stream and river banks that may be locally over steepened by erosion and thus unstable. Man-made slopes are assumed to be stable.

Land use consists of agricultural development of fruit and vegetable crops with isolated farmsteads and rare light industrial units. Infrastructure such as local roads and railroads as well as utilities including power and telecommunication transmission lines and water and sewer pipes are prevalent. The infrastructure is both beneath and above the ground.

Numerous natural braids and constrained channels of the Kings River and Kaweah Rivers emanating from the Sierra Nevada to the east pass through the area and are still likely to be capable of causing floods during or after high precipitation events in their watersheds. There are a number of major reservoirs and dams up slope of the site that could cause flooding should they be breached. In addition, there are a number of small ponds or reservoirs that may pose constraints to the project.

The area from Hanford to the north Corcoran is dominated by historical river channels trending typically north east to south west. An abundance of relict channels can be seen on historical aerial photography, which have subsequently been in filled or channelized to facilitate modern agricultural land.

Review of the historical aerial photography indicates an area of northwest - southeast trending large scale linear features cross cutting the route approximately 5 miles to the west of the town of Selma. The feature is interpreted to represent a dune field. The area has been identified to cover a strip of land approximately 6.5 miles by 2 miles, but may have covered a greater aerial extent than this.

The geologic map of the Kings River indicates the area is underlain by Recent Great Valley fan deposits (Q_f) and Recent Great Valley basin deposits (Q_b). These deposits are likely to be of fluvial origin and be composed of gravels, sands, silts and clays with potentially significant units of hard pan and organic soils. These soils combined with the possibility of elevated water tables associated with rivers increase the potential for liquefaction hazards.

It should be noted that our interpretation of the geology differs from that of the Jenkins (1965) geologic map with the identification of dune sand above the Great Valley Deposits between Fresno and the Kings River. The dune sands have, however, been identified on a USGS geologic

map prepared by Page (1986). Sediments associated with dune fields will typically comprise aeolian sand and silt deposits. Loess, sediment formed by the accumulation of windblown silt sized particles is typically associated with dune field settings and can be susceptible to liquefaction and collapse settlement.

Due to the low relief topography there were no significant areas of man-made cut or fill recorded. However, new areas of man-made cut or fill could have been developed since the last aerial photographs were taken.

There are several historic and potential future sources of aggregates within this section and in adjacent areas. These are likely to consist of fluvial sands and gravels.

In summary, the primary potential geohazards or constraints associated with this section are potential for flooding, localized high groundwater table, liquefaction hazards and unknown soil conditions (near surface and at depth) with potentially soft, compressible ground.

3.3 Tulare Lake Bed: Kansas Avenue, Corcoran to Colonel Allensworth State Historic Park

This study area extends from Kansas Avenue just north of Corcoran to the Colonel Allensworth State Historical Park predominately through rural land and is approximately 23 miles in length. The proposed alignment generally runs parallel to the existing northwest-southeast running Burlington Northern Santa Fe railroad either passing Corcoran to the east or diverging from the rail road and skirting Corcoran's eastern flank depending on which option is selected.

The topography of the site indicates gently undulating low relief terrain at an elevation of between 208 feet and 224 feet ASL. The gradients of the natural slopes are generally shallow and stable with the exception of localized stream and river banks that may be locally over steepened by erosion and thus unstable. Man-made slopes are assumed to be stable.

Land use consists of agricultural development of fruit and vegetable crops with scattered isolated farmsteads and rare, light industrial units. Infrastructure, such as local roads and railroads as well as utilities, including power and telecommunication transmission lines and water and sewer pipes, are prevalent. One of the options passes through urban Corcoran. Land uses in that corridor include commercial, light industrial and residential. Whether rural or urban, infrastructure such as local roads and railroads as well as utilities such as power and telecommunication transmission lines and water and sewer pipes should be anticipated. The infrastructure is both beneath and above the ground.

Many natural braids and constrained channels of the Tule River and Kaweah Rivers emanating from the Sierra Nevada to the east are seen to pass through the area. These many channels are still likely to be capable of causing floods during or after high precipitation events in their watersheds. There are a number of major reservoirs and dams up slope of the site that could cause flooding should they be breached. In addition there are a number of small ponds or reservoirs adjacent to the proposed alignment that may pose constraints to the project.

The geologic map of the Tulare Lake Bed area indicates the site is underlain by Quaternary lake deposits (Q_l), Recent Great Valley fan deposits (Q_f) and Recent Great Valley basin deposits (Q_b). These deposits are likely to be of lacustrine and fluvial origin and be composed of clays, organic soils, gravels, sands and silts. These soils may be soft and compressible due to the manner in which they were deposited. The presence of soft, organic soils could increase the potential for the 'Bow Wave Effect' associated with high speed trains.

Due to the low relief topography there were no significant areas of man-made cut or fill recorded. However, new areas of man-made cut or fill could have been developed since the last aerial photographs were taken.

There are several historic and potential future sources of aggregates within this section and in adjacent areas. These are likely to consist of fluvial sands and gravels.

In summary, the primary potential geohazards or constraints associated with this section are unknown soil conditions (near surface and at depth) with potentially soft, compressible ground, potential for flooding and a localized high groundwater table.

3.4 Wasco: Colonel Allensworth State Historic Park to Fresno Avenue, Shafter

This study area extends from Colonel Allensworth State Historic Park to Fresno Avenue just north of Shafter through rural land and is approximately 24.5 miles in length. There are two possible route alignments proposed; one alignment runs parallel to the existing approximately north-south running Burlington Northern Santa Fe railroad and a second alignment that runs subparallel to the approximately north-south running Burlington Northern Santa Fe railroad but to the west of the rail road for the northern part of this section and to the east of the rail road for the southern part of the section. The alignments are apart at the beginning and end of the section and cross over in the middle approximately 4 miles north of Wasco.

The topography of the site indicates gently undulating low relief terrain at an elevation of between 224 feet and 370 feet ASL. The gradients of the natural slopes are generally shallow and stable with the exception of localized stream and river banks that may be locally over steepened by erosion and thus unstable. Man-made slopes are assumed to be stable.

Land use consists of agricultural development of fruit and vegetable crops with scattered isolated farmsteads and rare, light industrial units. Infrastructure, such as local roads and railroads as well as utilities, including power and telecommunication transmission lines and water and sewer pipes, are prevalent. The infrastructure is both beneath and above the ground. In addition, some abandoned and operation oil and gas wells are likely to be within or adjacent to the alignment.

Some natural and constrained channels of the Poso Creek and other unnamed ephemeral channels emanating from the Sierra Nevada to the east pass through the area and are still likely to be capable of causing floods during or after high precipitation events in their watersheds. In addition, there are numerous of indicators of wet boggy ground, small ponds or reservoirs adjacent to the proposed alignment that may pose constraints to the project.

The geologic map of the Wasco area indicates it is underlain by Recent Great Valley fan deposits (Q_f) and Recent Great Valley basin deposits (Q_b). These deposits are likely to be of fluvial origin and be composed of gravels, sands, silts and clays with potentially significant units of organic soils. These soils combined with the possibility of elevated water tables associated with rivers increase the potential for liquefaction hazards. The Poso Creek Pond Fault is shown in this area.

Due to the low relief topography there were no significant areas of man-made cut or fill recorded. However, new areas of man-made cut or fill could have been developed since the last aerial photographs were taken.

There are several historic and potential future sources of aggregates within this section and in adjacent areas. These are likely to consist of fluvial sands and gravels.

A review of the historical aerial photography shows an abundance of ponds located within this area. This would indicate that historically the groundwater level in this area was higher than

current levels with the increased likelihood of deposition of organic soils. The presence of soft organic soils could increase the potential for the 'Bow Wave Effect' associated with high speed trains. In summary, the primary potential geohazards or constraints associated with this section are potential for flooding and localized high groundwater table, liquefaction hazards, unknown soil conditions (near surface and at depth) with potentially soft compressible ground and abandoned or operational oil and gas wells.

3.5 Bakersfield: Fresno Avenue, Shafter to Oswell Street

This study area extends from Fresno Avenue, Shafter to the southern limit of the FB segment at Oswell Street and is approximately 24.5 miles in length. There are two possible route alignments proposed for the northern part of this section as the alignments start apart; one alignment runs parallel to the existing approximately northwest-southeast running Burlington Northern Santa Fe railroad and passes through Shafter and a second alignment that runs subparallel to the Burlington Northern Santa Fe railroad but to the east of Shafter. The route alignments join approximately 5 miles southeast of Shafter and then slightly bifurcate and intertwine through Bakersfield.

The topography of the site indicates gently undulating low relief terrain at an elevation of between 347 feet and 531 feet ASL. The gradients of the natural slopes are generally shallow and stable with the exception of localized stream and river banks that may be locally over steepened by erosion and thus unstable. Man-made slopes are assumed to be stable.

Land use between Shafter and Rosedale, northwest of Bakersfield has historically consisted of agricultural development of fruit and vegetable crops with scattered isolated farmsteads and rare, light industrial units. Land use within Bakersfield is generally set to urban uses such as commercial, light industrial, residential with associated infrastructure such as local roads, interstate roads and railroads as well as utilities, including power and telecommunication transmission lines and water and sewer pipes. The urban infrastructure is on many levels beneath and above the ground.

A number of rivers and streams including the Kern River and Poso Creek emanate from the Sierra Nevada to the east and pass through the area. Some of these water courses are now in culverts or canals particularly through the urban areas, but are still likely to be capable of causing floods during or after high precipitation events in their watersheds. There are a number of small reservoirs and dams up slope of the site which should they be breached will cause flooding across the site. In addition there are a number of small ponds or reservoirs adjacent to the proposed alignment that may pose constraints to the project.

A review of the historical aerial photography shows an abundance of ponds located within this area. This would indicate that historically the groundwater level in this area was higher than current levels with the increased likelihood of deposition of organic soils. The presence of soft organic soils could increase the potential for the 'Bow Wave Effect' associated with high speed trains.

The geologic map of the Bakersfield area indicates it is underlain by Pleistocene nonmarine deposits (Q_c), Recent Great Valley fan deposits (Q_f) between Shafter and Bakersfield, Recent Great Valley stream channel deposits (Q_{sc}) localized where the alignment crosses the Kern River and Recent Great Valley basin deposits (Q_b) east of the Kern River. These deposits are likely to be of fluvial origin and be composed of gravels, sands, silts and clays with surficial organic soils. These soils combined with the possibility of elevated water tables associated with rivers increase the potential for liquefaction hazards.

Due to the low relief topography there were no significant areas of man-made cut or fill recorded. However, new areas of man-made cut or fill could have been developed since the last aerial photographs were taken.

There are several historic and potential future sources of aggregates within this section and in adjacent areas. These are likely to consist of fluvial sands and gravels.

In summary, the primary potential geohazards or constraints associated with this section are existing buildings and infrastructure, unknown soil conditions (near surface and at depth), potential for flooding, liquefaction hazards, ground shaking from various nearby faults identified in this report and abandoned or operational oil and gas wells.

4.0 Conclusions and Recommendations

The following general hazards and constraints have been identified as part of the aerial photography interpretation:

- Urban areas with associated structures and infrastructure,
- Existing rail road crossings and the existing rail road adjacent to proposed alignment,
- Interstate, highway and minor road crossings,
- Rural agricultural land, farmsteads and associated infrastructure,
- River crossings,
- Buried infilled river channels,
- Flooding,
- Soft compressible soils associated with low energy depositional environments such as the Tulare Lake Bed and oxbow lakes etc. associated with current and historic river channels,
- Collapsible soils associated with dune sands etc.
- Existing and infilled ponds and reservoirs,
- Liquefaction hazards,
- Ground shaking,
- Abandoned or operation water, oil and gas wells.

The location of these hazards and constraints are presented in the GIS file and shown in Figures B1 and B3 to B7.

It is recommended that a thorough walk over survey is carried out by a suitably qualified geoprofessional to verify and supplement the findings of this study and the remainder of this report.

5.0 References

Ray, R., G. 1962. Aerial Photographs in Geologic Interpretation and Mapping, Geological Survey Professional Paper 373. United States Government Printing Office, Washington.

Avery, T., E., and Berlin, G., L. 1985. Interpretation of Aerial Photographs, Fourth Edition. Burgess Publishing Company, Minnesota.

Ho H. Y., King, J. P. and Wallace, M. I. 2006. A Basic Guide to Air Photo Interpretation in Hong Kong, Applied Geoscience Centre, Hong Kong.

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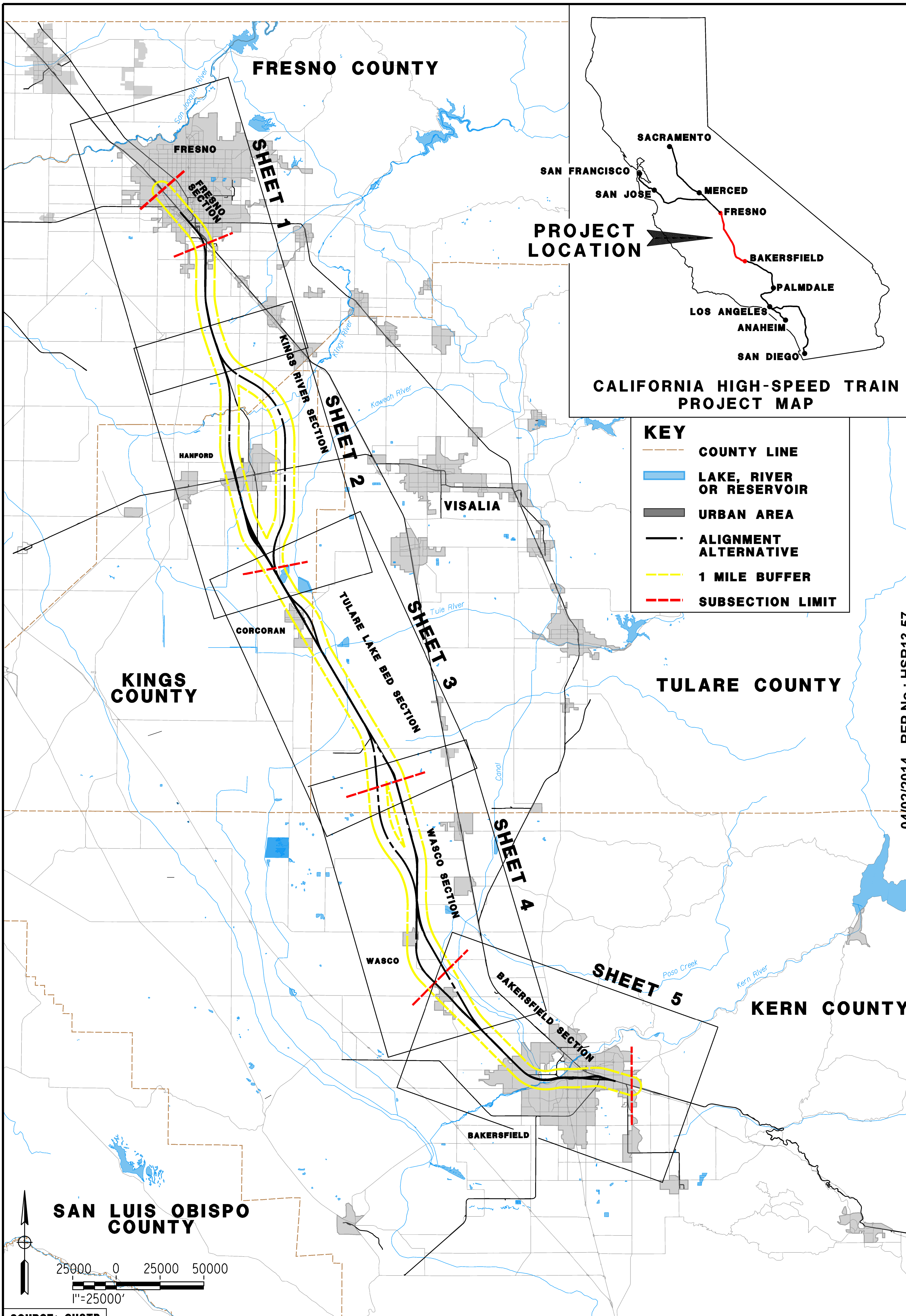


URS | HMM | ARUP CALIFORNIA HIGH-SPEED TRAIN

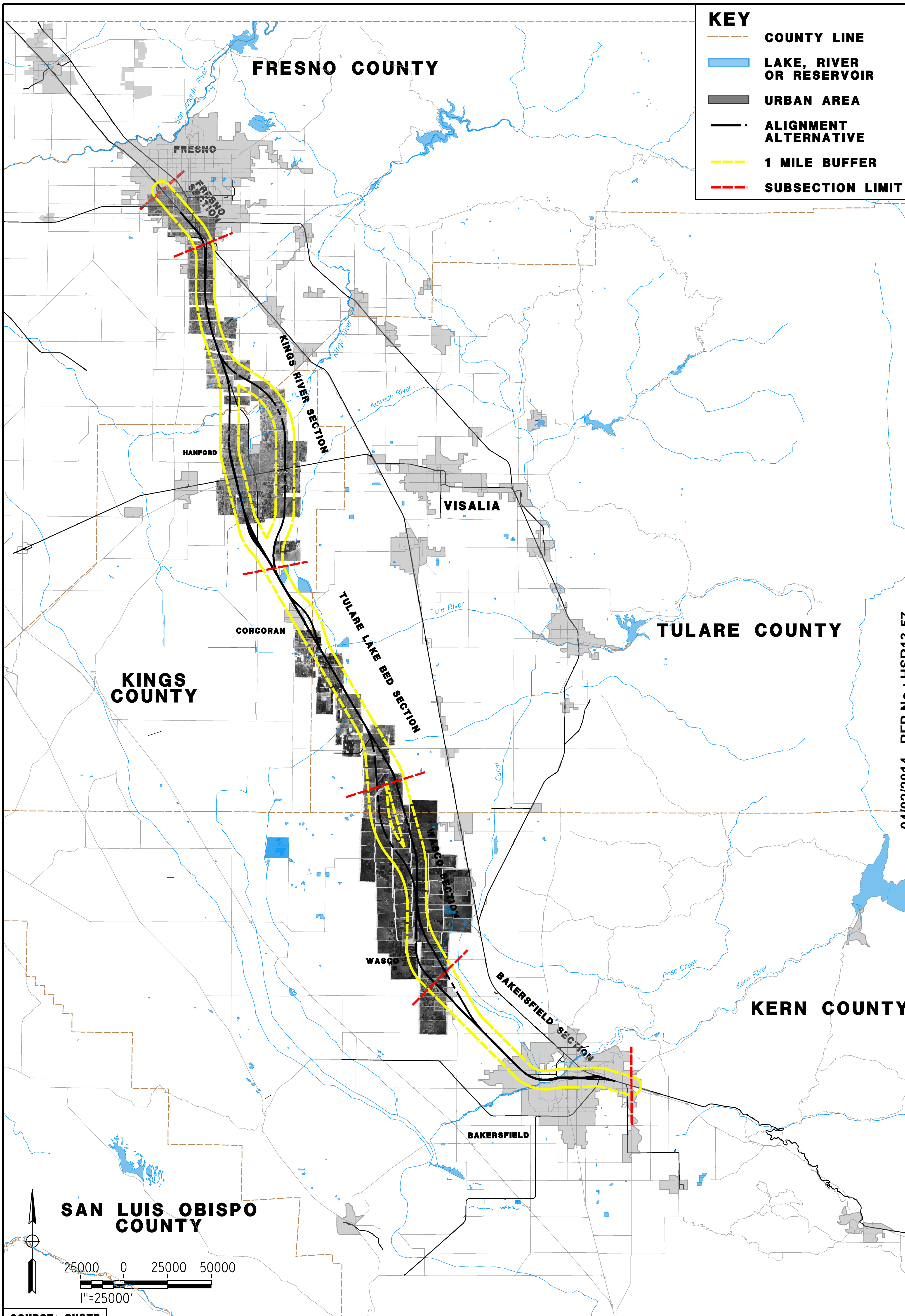
CALIFORNIA HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD

SITE LOCATION
AND
KEY PLAN

FIGURE NO.	B1
DATE	DECEMBER 2013
SHEET NO.	1 OF 1

$FILE$
$USER$ $TIME$



SOURCE: CHSTP

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

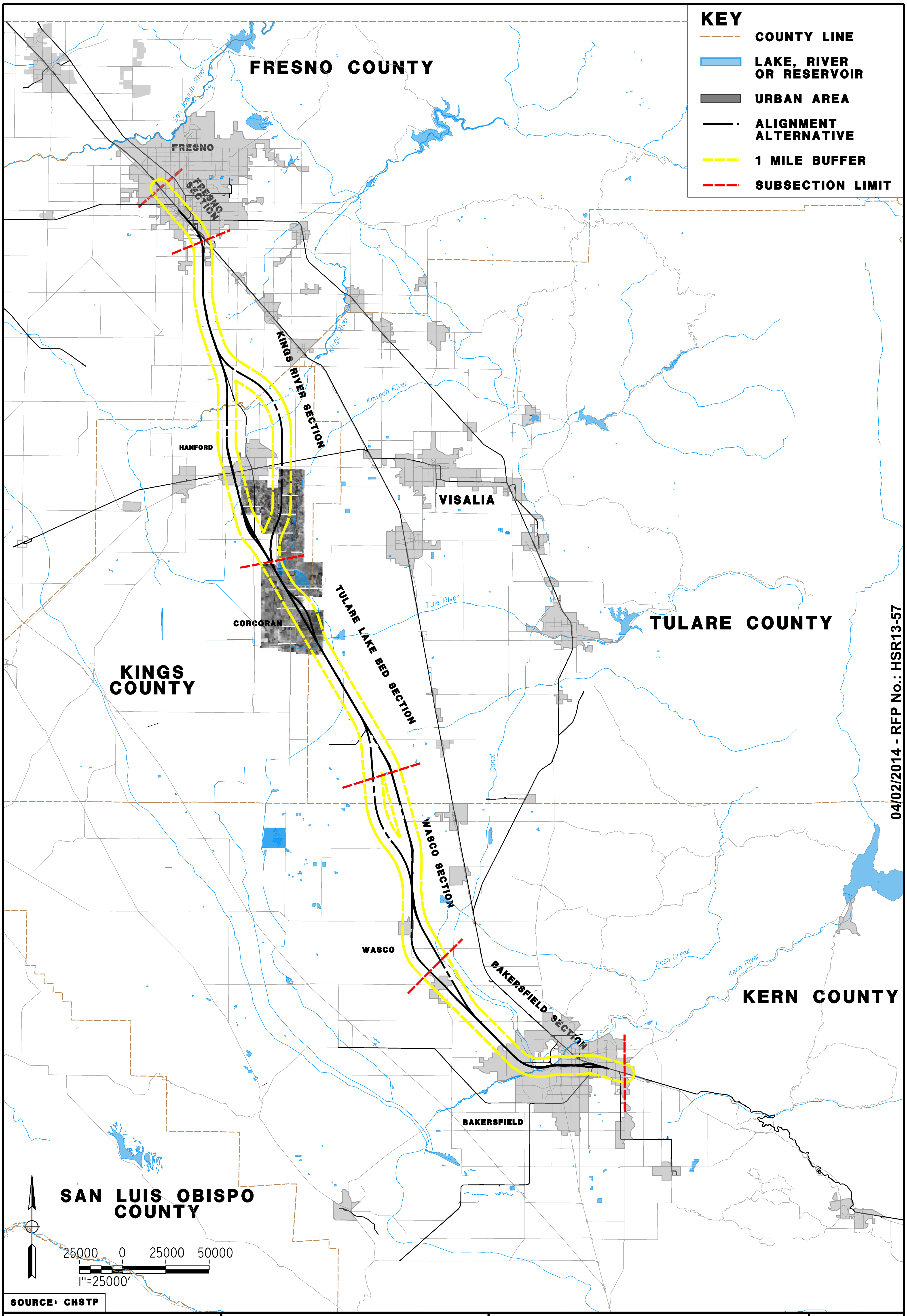
CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD

1937 AERIAL PHOTOGRAPHY

FIGURE NO.	B2a
DATE	DECEMBER 2013
SHEET NO.	1 OF 13

\\global\americas\Jobs\S-F\31000\31577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\TWB Aerial Interpretation\FIG B2a_AERIAL .dgn
Jodi.Borghesi 1:48:03 PM



URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

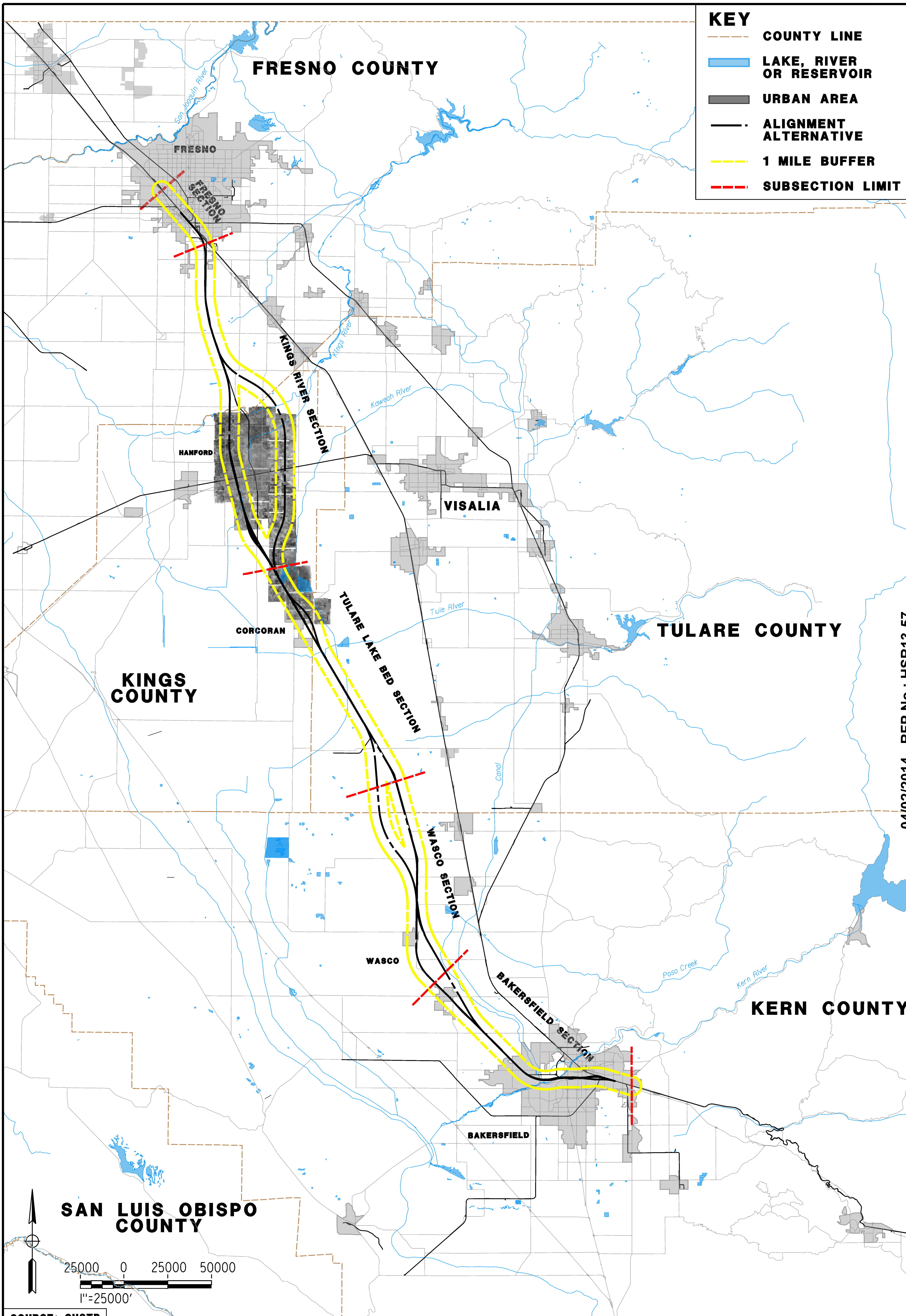
CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD

1940 AERIAL PHOTOGRAPHY

FIGURE NO.	B2b
DATE	DECEMBER 2013
SHEET NO.	2 OF 13

\\global\americas\Jobs\S-F\31000\31577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\TWB Aerial Interpretation\FIG B2b_AERIAL.dgn
Jodi.Borghesi 1:48:44 PM



04/02/2014 - RFP No.: HSR13-57

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD

1942 AERIAL PHOTOGRAPHY

FIGURE NO.	B2c
DATE	DECEMBER 2013
SHEET NO.	3 OF 13

\\global\americas\Jobs\S-F\31000\31577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\TWB Aerial Interpretation\FIG B2c_AERIAL .dgn
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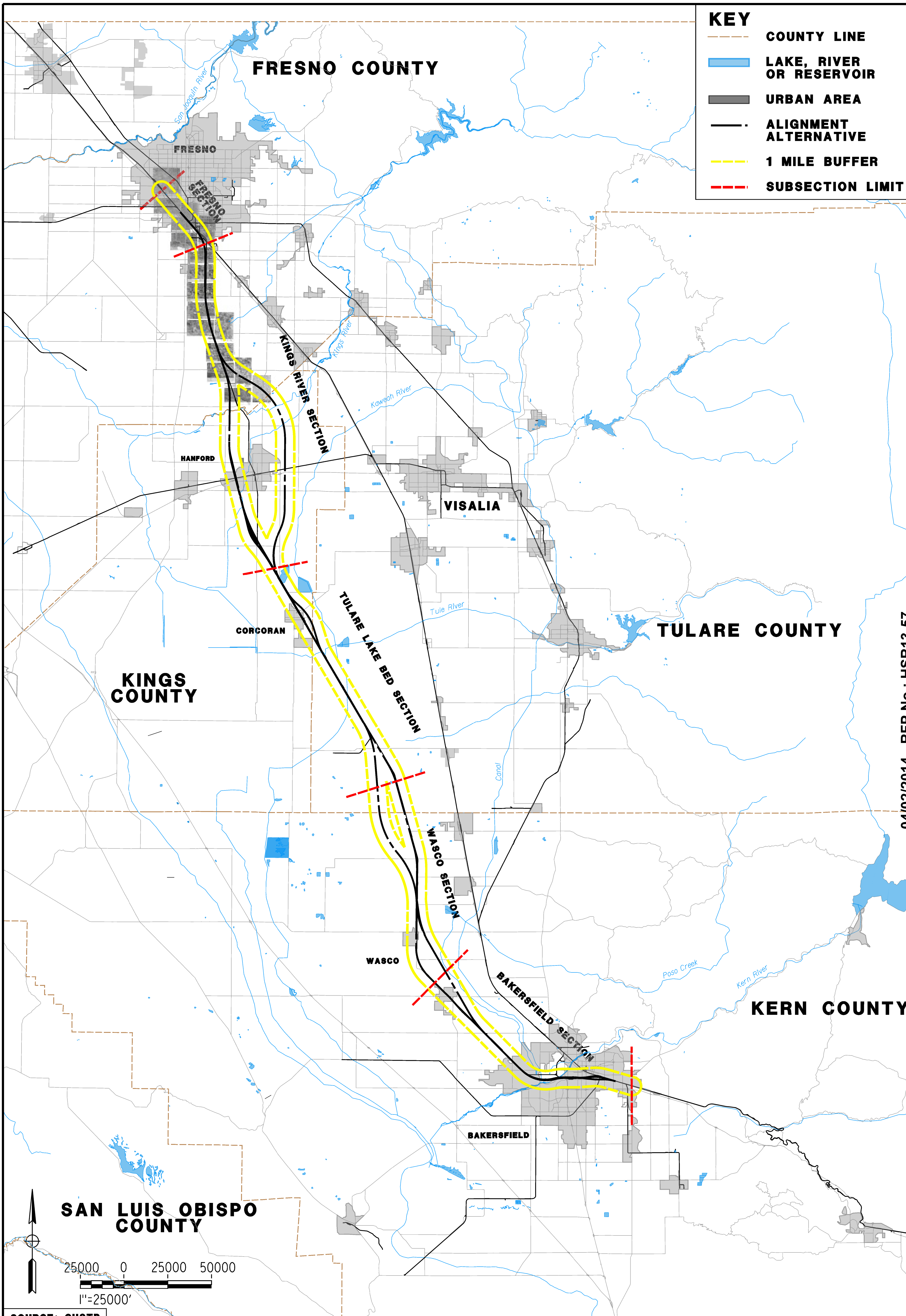

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD

1950 AERIAL PHOTOGRAPHY

FIGURE NO. B2d

DATE DECEMBER 2013

SHEET NO. 4 OF 13

\\global\americas\Jobs\S-F\31000\31577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\TWB Aerial Interpretation\FIG B2d_AERIAL.dgn
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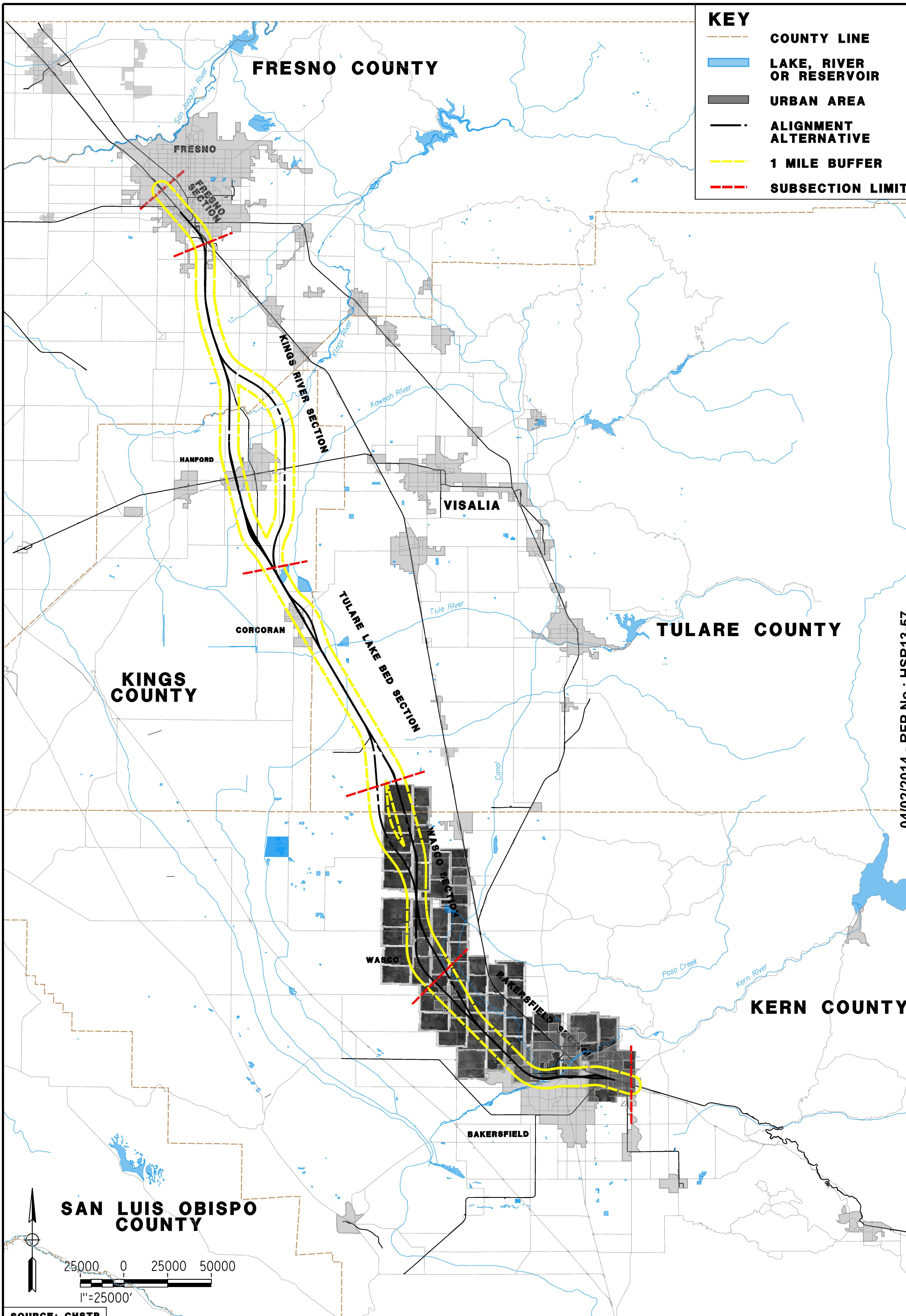


URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD

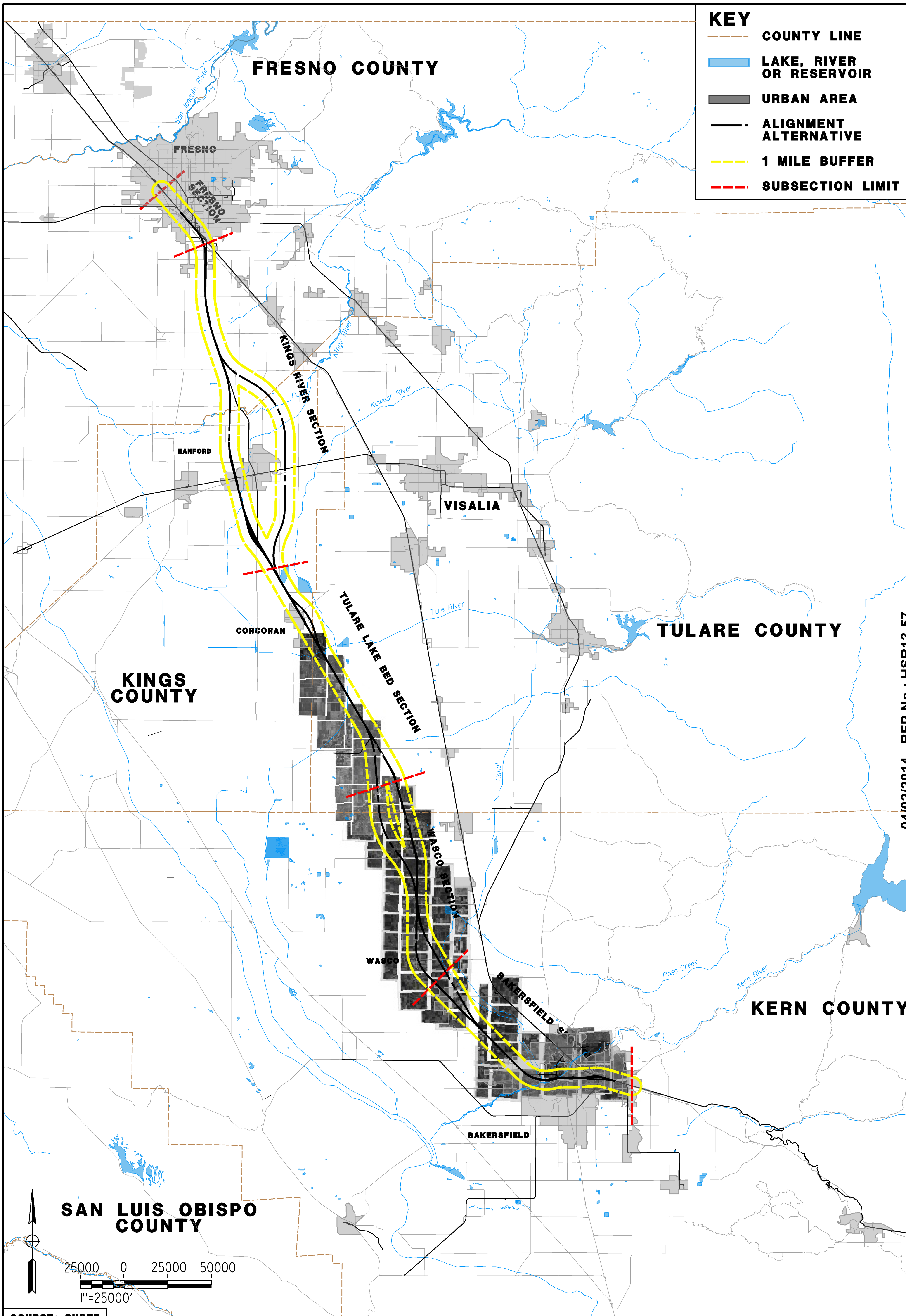
1952 AERIAL PHOTOGRAPHY

FIGURE NO. B2e

DATE DECEMBER 2013

SHEET NO. 5 OF 13

\\global\americas\Jobs\S-F\31000\31577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\TWB Aerial Interpretation\FIG B2e_AERIAL .dgn
Jodi.Borghesi 1:51:01 PM



URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD

1956 AERIAL PHOTOGRAPHY

FIGURE NO.	B2f
DATE	DECEMBER 2013
SHEET NO.	6 OF 13

\\global\americas\Jobs\S-F\31000\31577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\TWB Aerial Interpretation\FIG B2f_AERIAL.dgn
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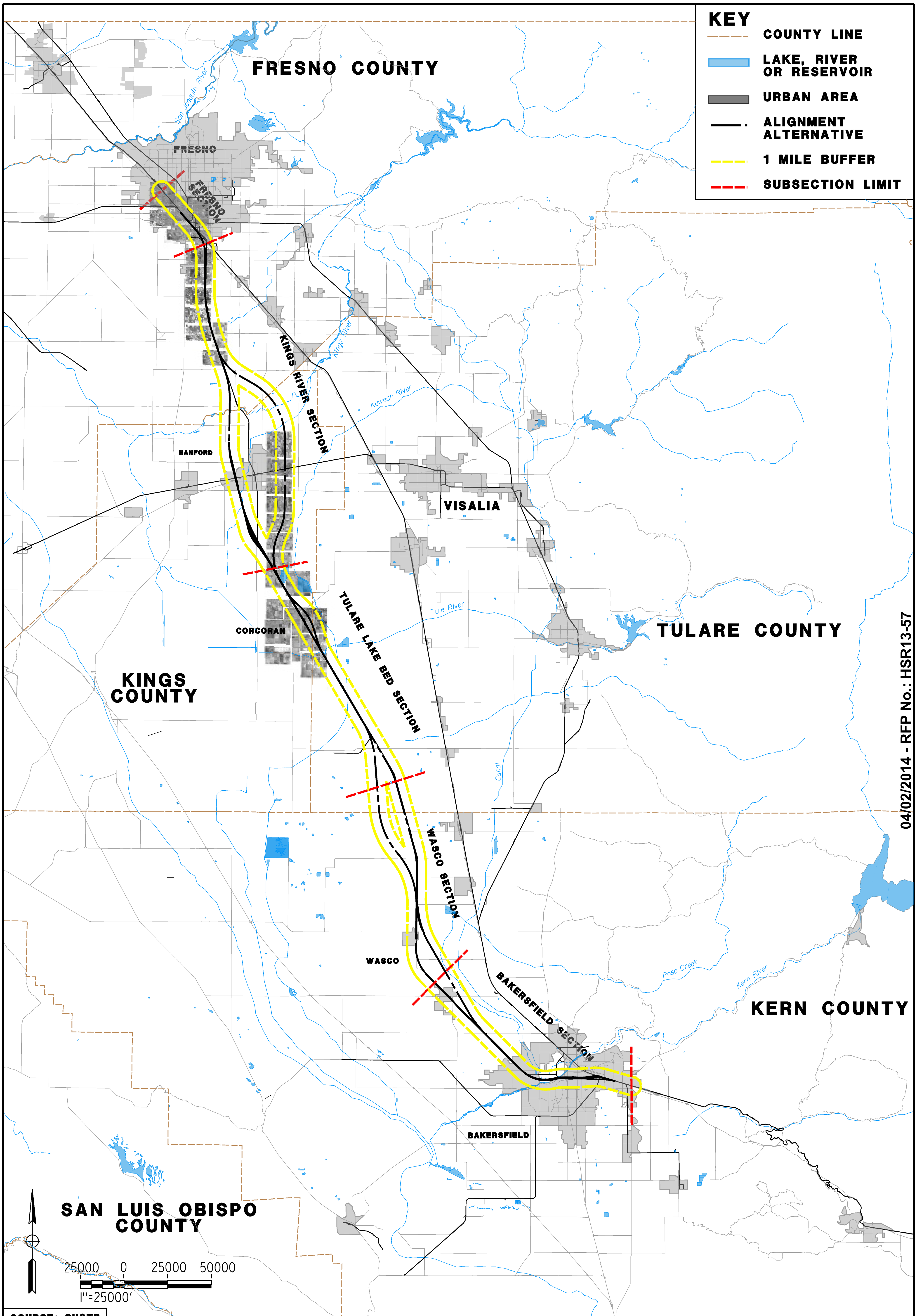


SOURCE: CHSTP

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

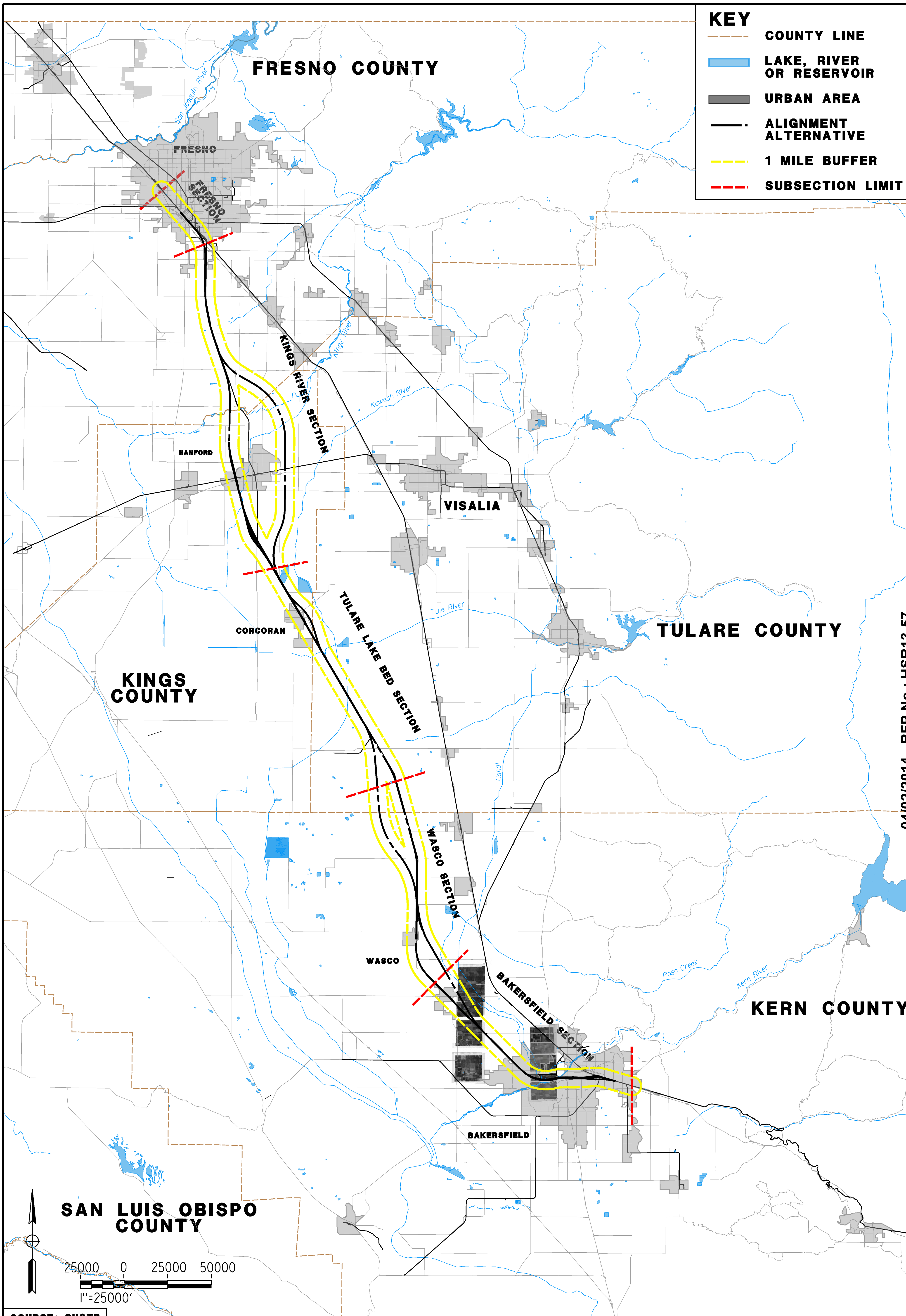
CALIFORNIA HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD

1957 AERIAL PHOTOGRAPHY

FIGURE NO. B2g
DATE DECEMBER 2013
SHEET NO. 7 OF 13

\\global\americas\Jobs\S-F\31000\31577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\TWB Aerial Interpretation\FIG B2g_AERIAL.dgn
Jodi.Borghesi 1:52:46 PM



04/02/2014 - RFP No.: HSR13-57

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD

1958 AERIAL PHOTOGRAPHY

FIGURE NO. B2h
DATE DECEMBER 2013
SHEET NO. 8 OF 13

\\global\americas\Jobs\S-F\31000\31577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\TWB Aerial Interpretation\FIG B2h_AERIAL .dgn
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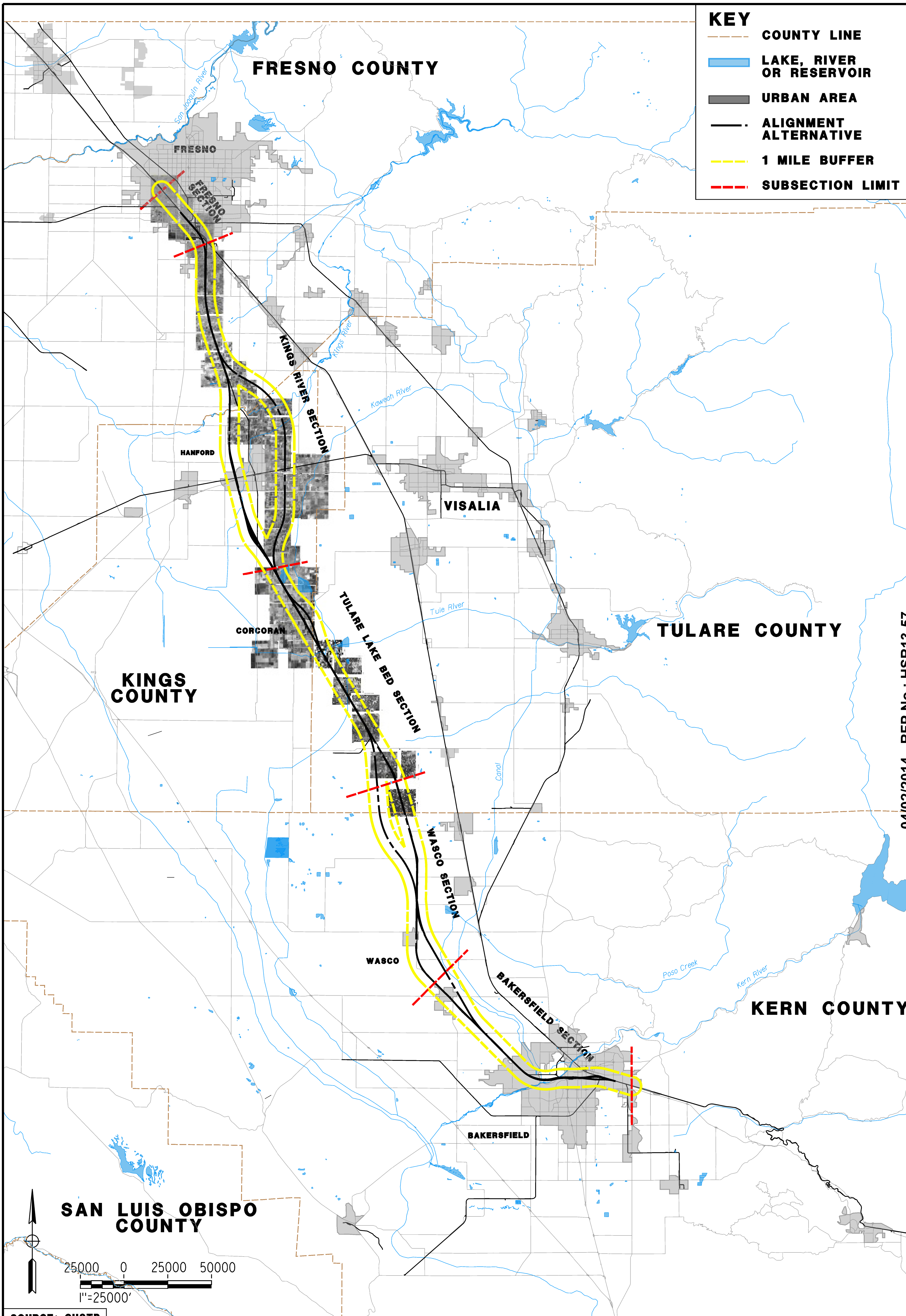


URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

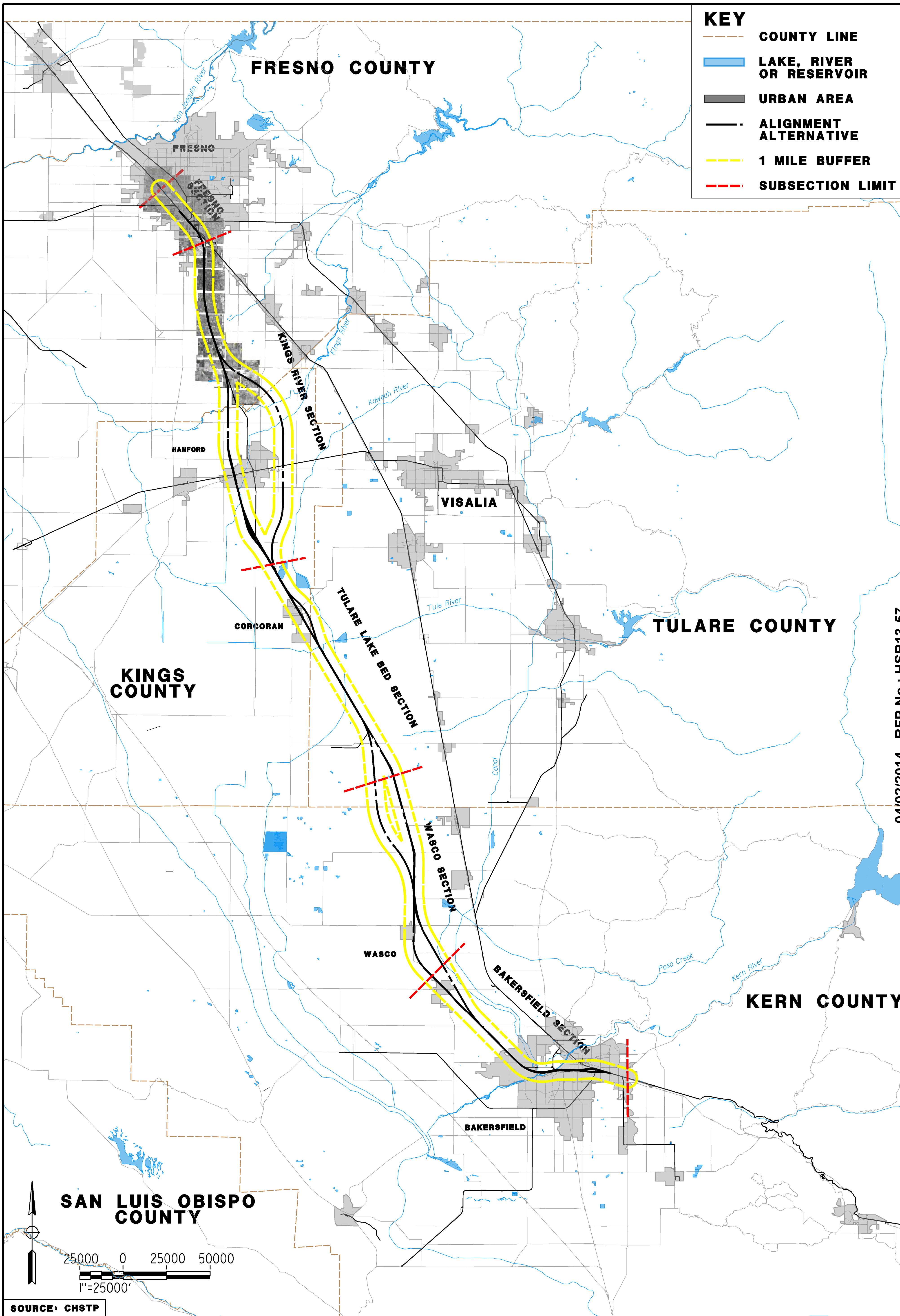
CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD

1961 AERIAL PHOTOGRAPHY

FIGURE NO.	B2i
DATE	DECEMBER 2013
SHEET NO.	9 OF 13

\\global\americas\Jobs\S-F\31000\31577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\TWB Aerial Interpretation\FIG B2I_AERIAL .dgn
Jodi.Borghesi 1:54:15 PM



URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD

1965 AERIAL PHOTOGRAPHY

FIGURE NO.	B2j
DATE	DECEMBER 2013
SHEET NO.	10 OF 13

\\global\americas\Jobs\S-F\31000\31577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\TWB Aerial Interpretation\FIG B2j_AERIAL.dgn
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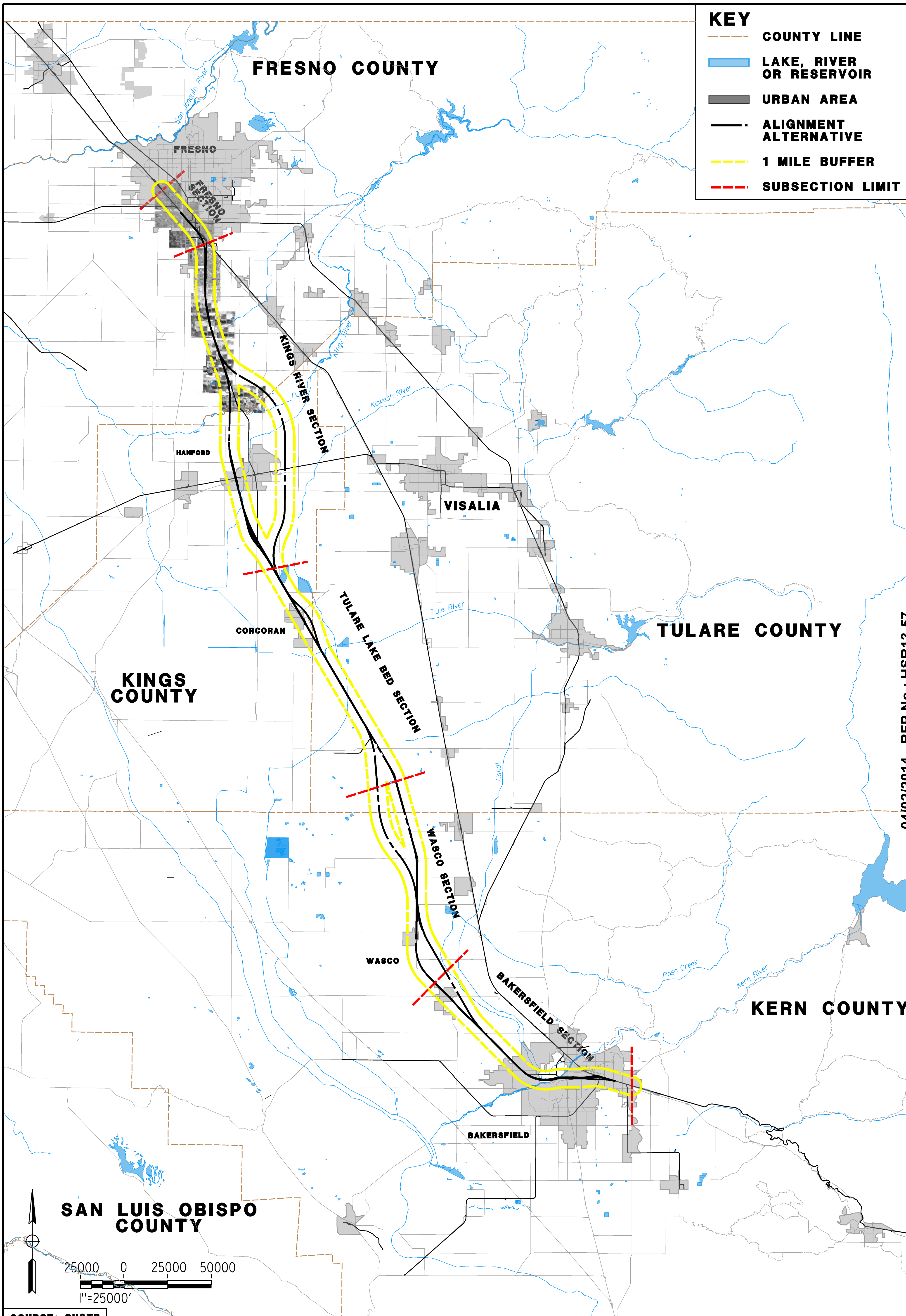

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD

1973 AERIAL PHOTOGRAPHY

FIGURE NO.	B21
DATE	DECEMBER 2013
SHEET NO.	12 OF 13

\\global\americas\Jobs\S-F\31000\31577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\TWB Aerial Interpretation\FIG B21_AERIAL .dgn
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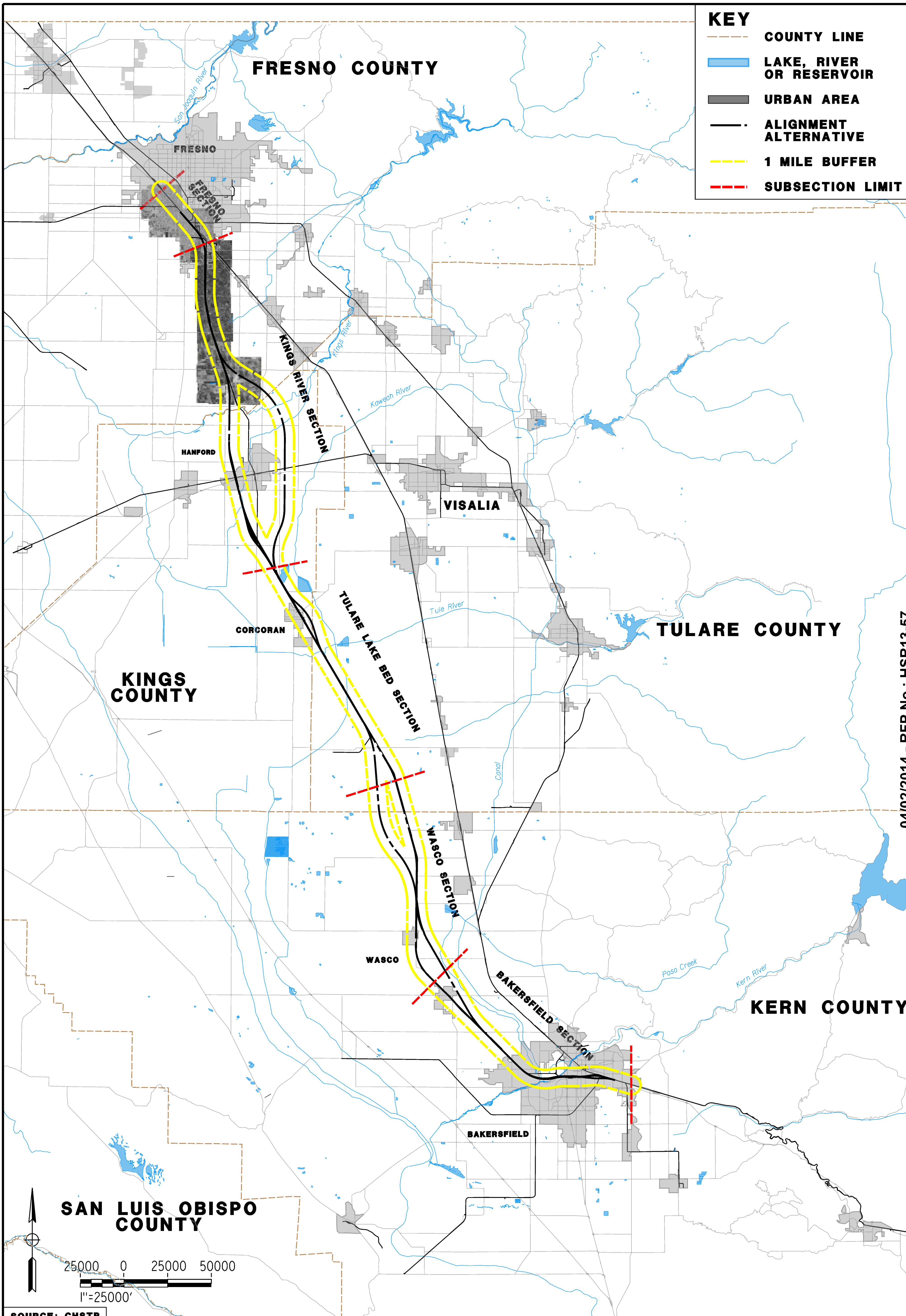

04/02/2014 - RFP No.: HSR13-57

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD

1977 AERIAL PHOTOGRAPHY

FIGURE NO. B2m

DATE DECEMBER 2013

SHEET NO. 13 OF 13

\\global\americas\Jobs\S-F\31000\31577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\TWB Aerial Interpretation\FIG B2m_AERIAL.dgn
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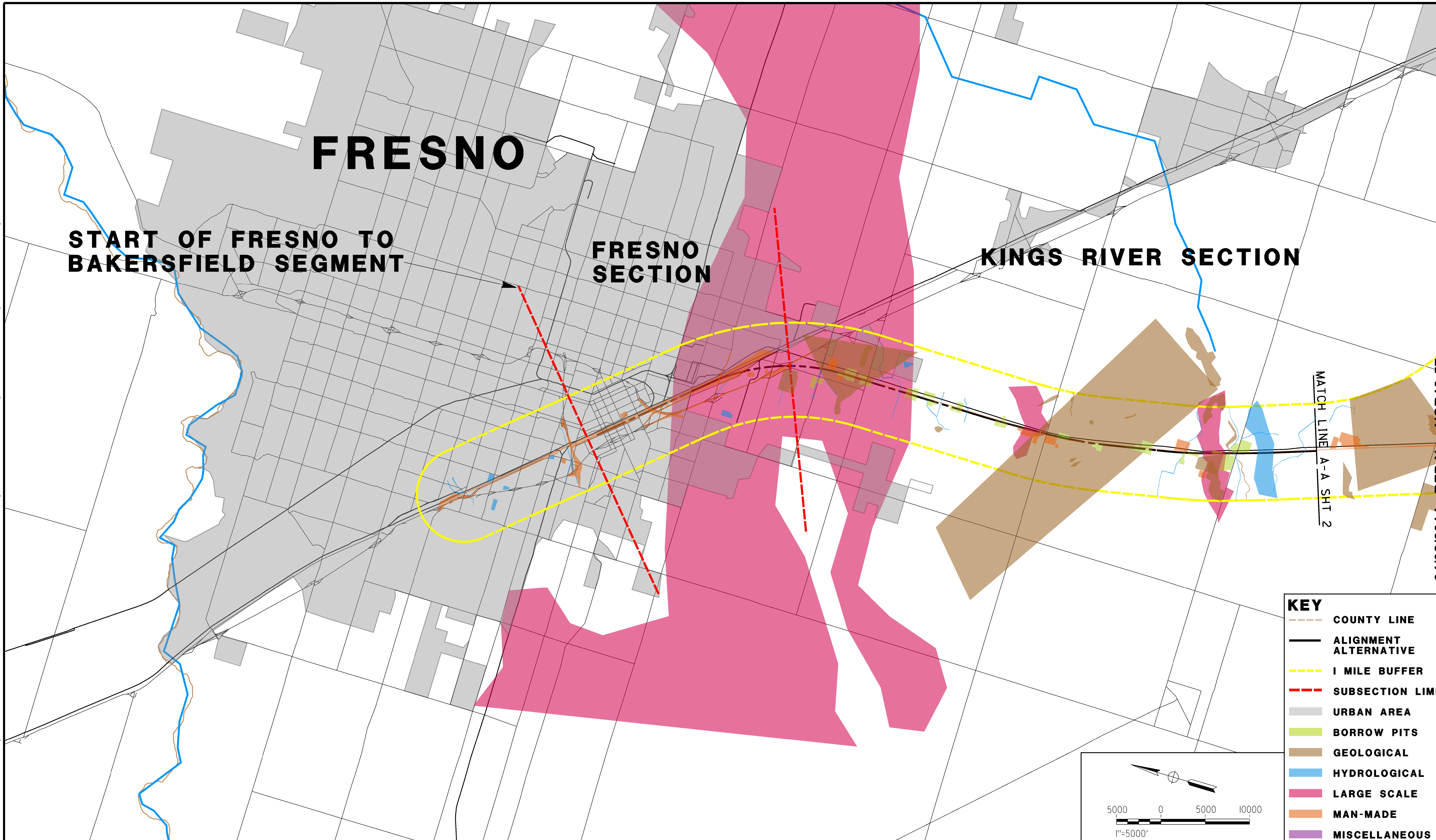


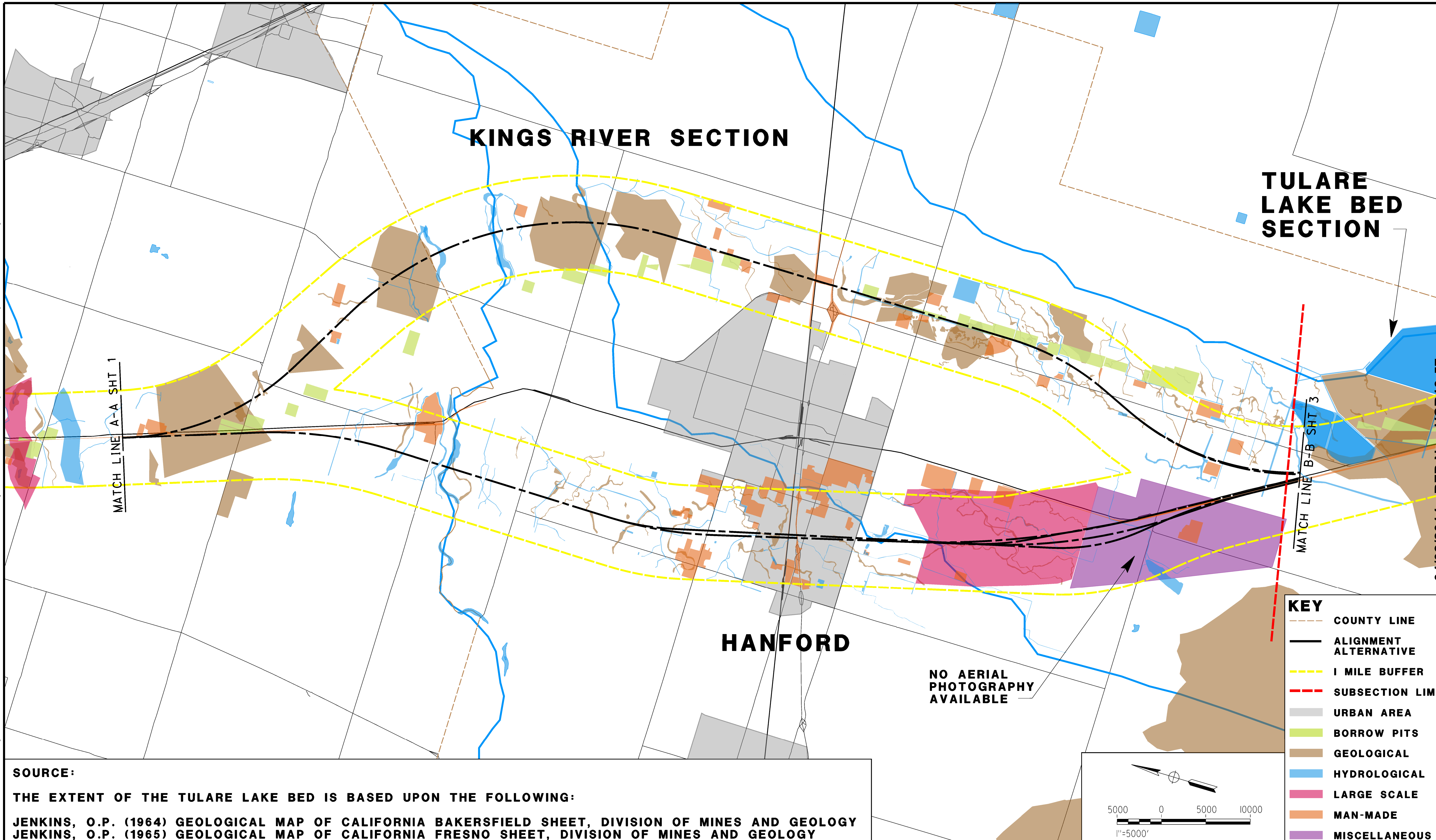
URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
INTERPRETED GEOHAZARDS AND CONSTRAINTS FOR FRESNO AND KINGS RIVER

FIGURE NO.	B3
DATE	DECEMBER 2013
SHEET NO.	1 of 5

Jodi.Borghesi 12/13/2013 2:00:50 PM \\global\americas\Jobs\S-F\131000\131577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\TWB Aerial Interpretation\FIG B3_AE



SOURCE:

THE EXTENT OF THE TULARE LAKE BED IS BASED UPON THE FOLLOWING:

JENKINS, O.P. (1964) GEOLOGICAL MAP OF CALIFORNIA BAKERSFIELD SHEET, DIVISION OF MINES AND GEOLOGY
JENKINS, O.P. (1965) GEOLOGICAL MAP OF CALIFORNIA FRESNO SHEET, DIVISION OF MINES AND GEOLOGY

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
INTERPRETED GEOHAZARDS AND CONSTRAINTS FOR KINGS RIVER

FIGURE NO. B4
DATE DECEMBER 2013
SHEET NO. 2 OF 5

04/02/2014 - RFP No.: HSR13-57

\\global\americas\Jobs\S-F\131000\131577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\TWB Aerial Interpretation\FIG B4_AE
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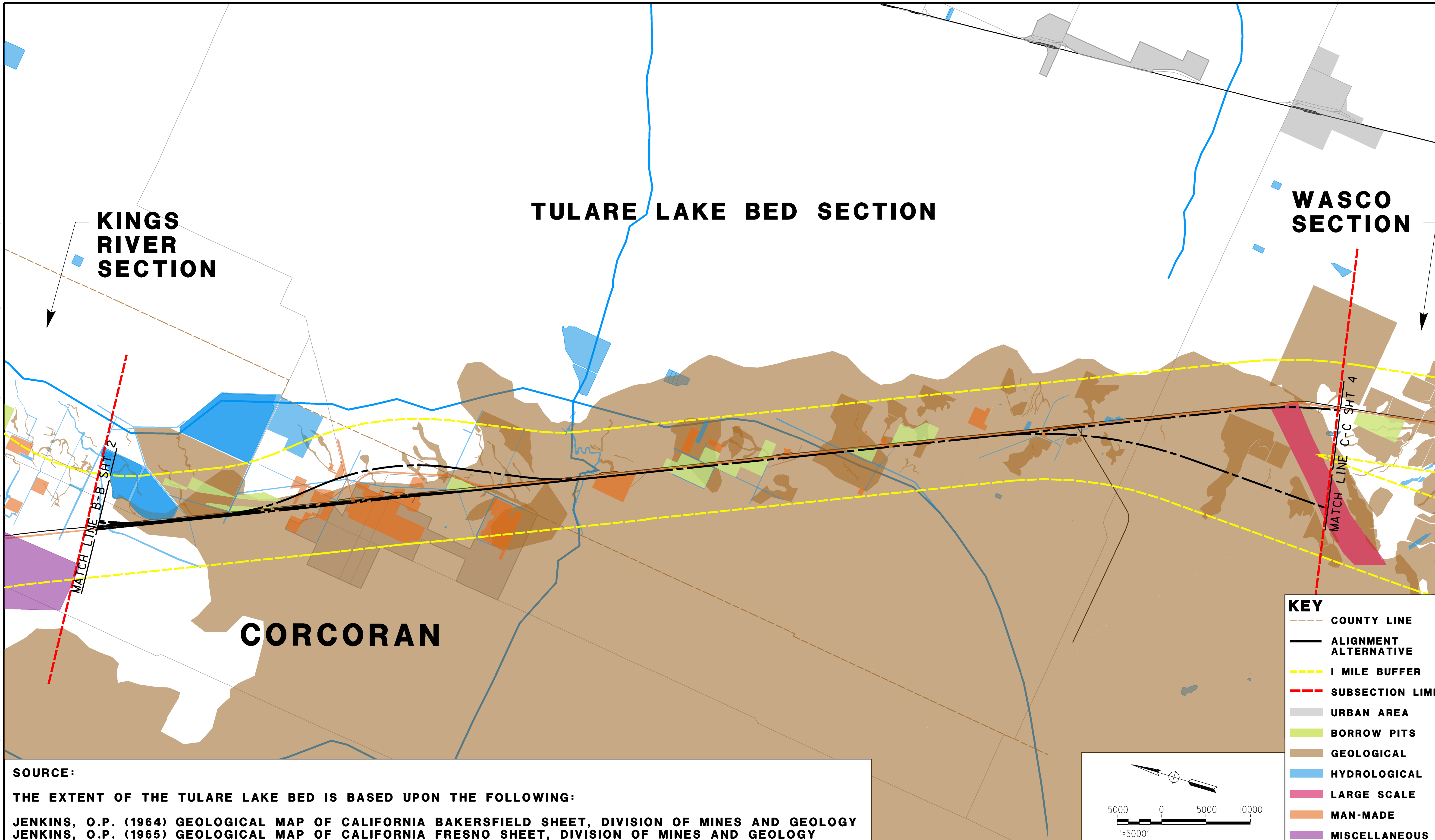
Jodi.Borghesi



SOURCE:

THE EXTENT OF THE TULARE LAKE BED IS BASED UPON THE FOLLOWING:

JENKINS, O.P. (1964) GEOLOGICAL MAP OF CALIFORNIA BAKERSFIELD SHEET, DIVISION OF MINES AND GEOLOGY
JENKINS, O.P. (1965) GEOLOGICAL MAP OF CALIFORNIA FRESNO SHEET, DIVISION OF MINES AND GEOLOGY

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
INTERPRETED GEOHAZARDS AND CONSTRAINTS FOR TULARE LAKE BED

FIGURE NO. B5
DATE DECEMBER 2013
SHEET NO. 3 of 5

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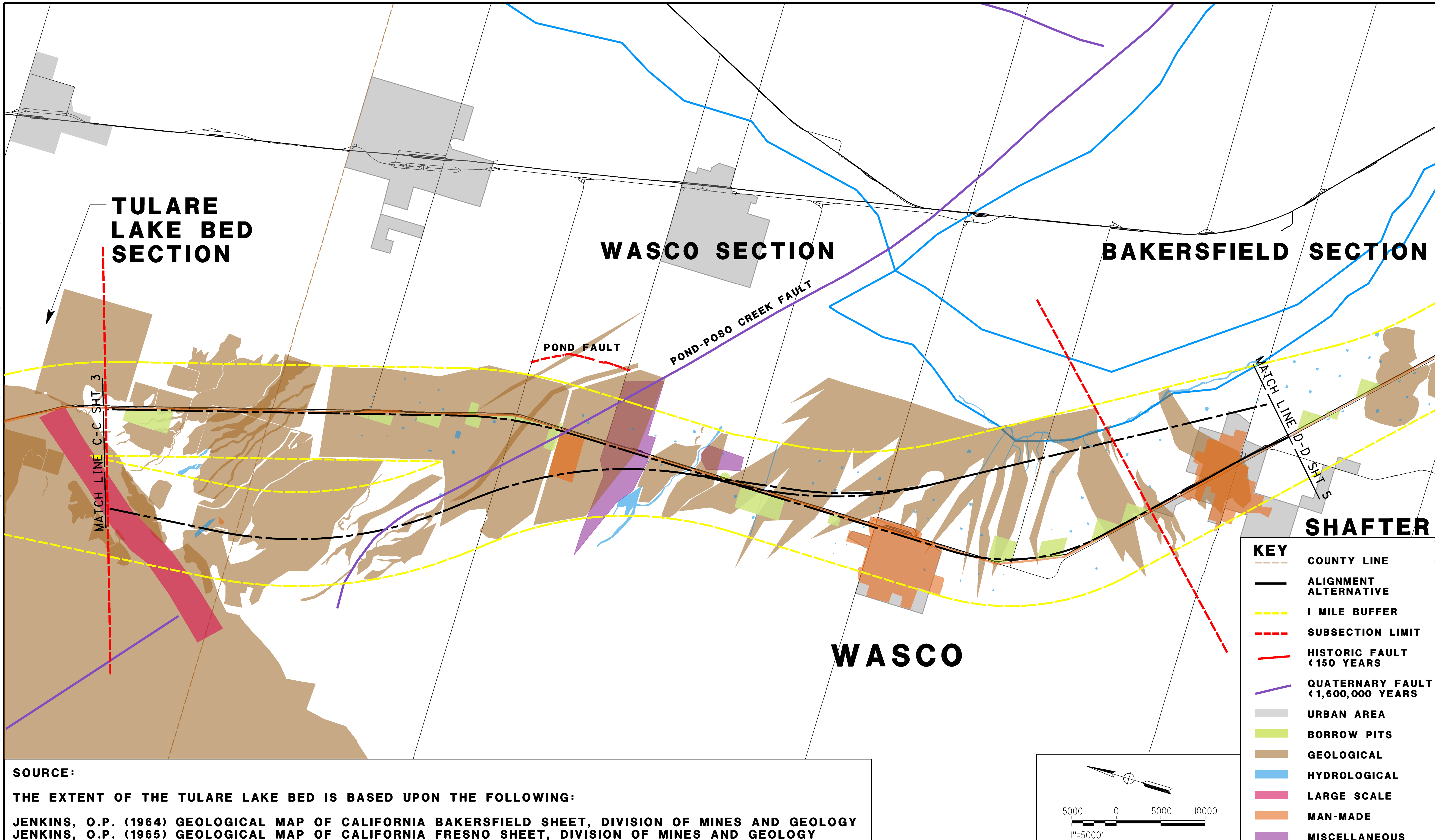
Jodi.Borghesi



SOURCE:

THE EXTENT OF THE TULARE LAKE BED IS BASED UPON THE FOLLOWING:

JENKINS, O.P. (1964) GEOLOGICAL MAP OF CALIFORNIA BAKERSFIELD SHEET, DIVISION OF MINES AND GEOLOGY
JENKINS, O.P. (1965) GEOLOGICAL MAP OF CALIFORNIA FRESNO SHEET, DIVISION OF MINES AND GEOLOGY

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

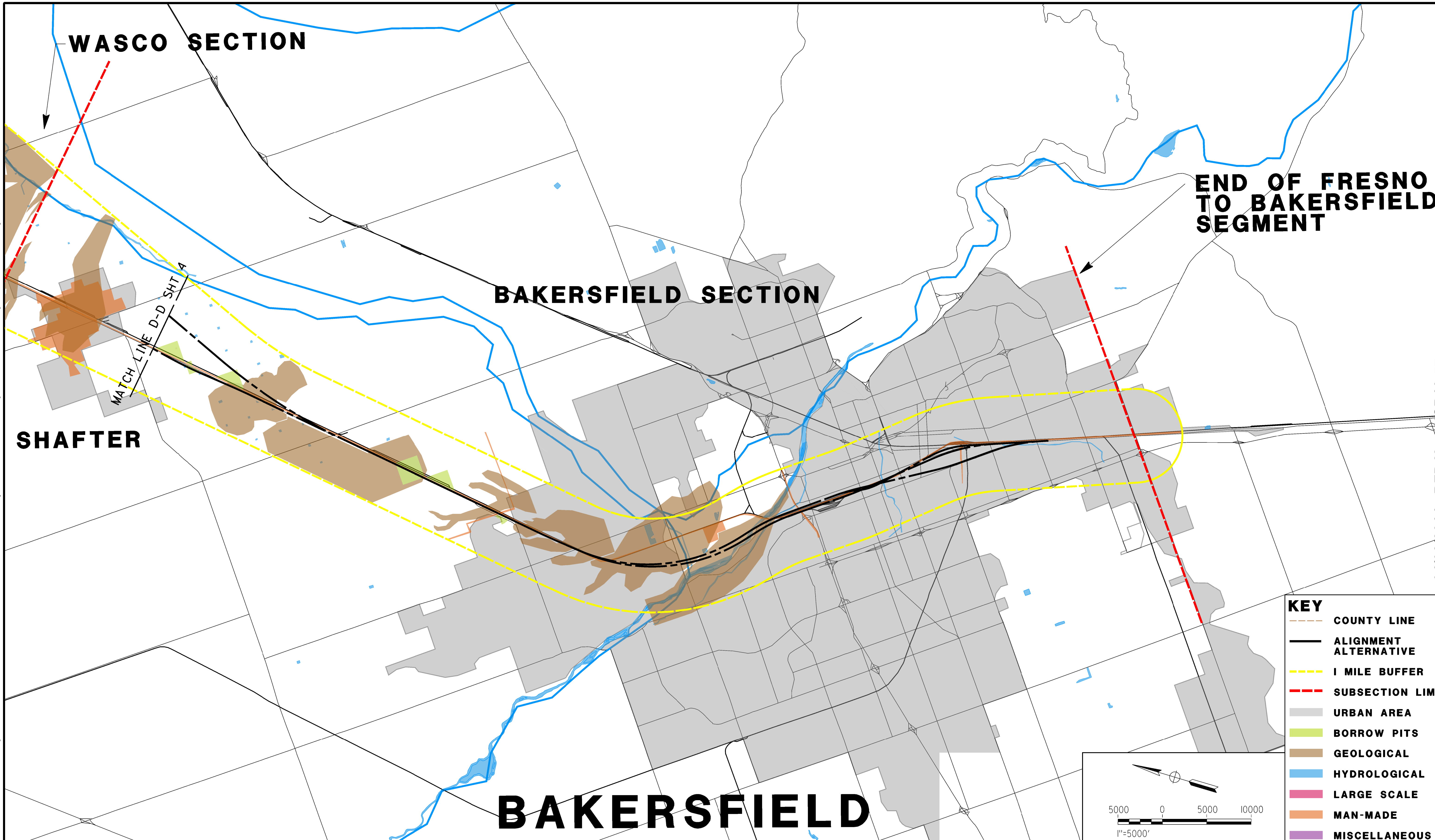
CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
INTERPRETED GEOHAZARDS AND CONSTRAINTS FOR
WASCO AND BAKERSFIELD

FIGURE NO. B6
DATE DECEMBER 2013
SHEET NO. 4 of 5

04/02/2014 - RFP No.: HSR13-57

Jodi.Borghesi 12/13/2013 2:27:50 PM \\global\americas\Jobs\S-F\131000\131577\4 Internal Project Data\4-03 Drawings\4-03-01 15% Design\4-03-01-05 Design Sheets\Geotech\TWB Aerial Interpretation\FIG B7_AE



04/02/2014 - RFP No.: HSR13-57

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
INTERPRETED GEOHAZARDS AND CONSTRAINTS
BAKERSFIELD

FIGURE NO. B7
DATE DECEMBER 2103
SHEET NO. 5 of 5

Appendix C

Archeological Test Pits

Figures

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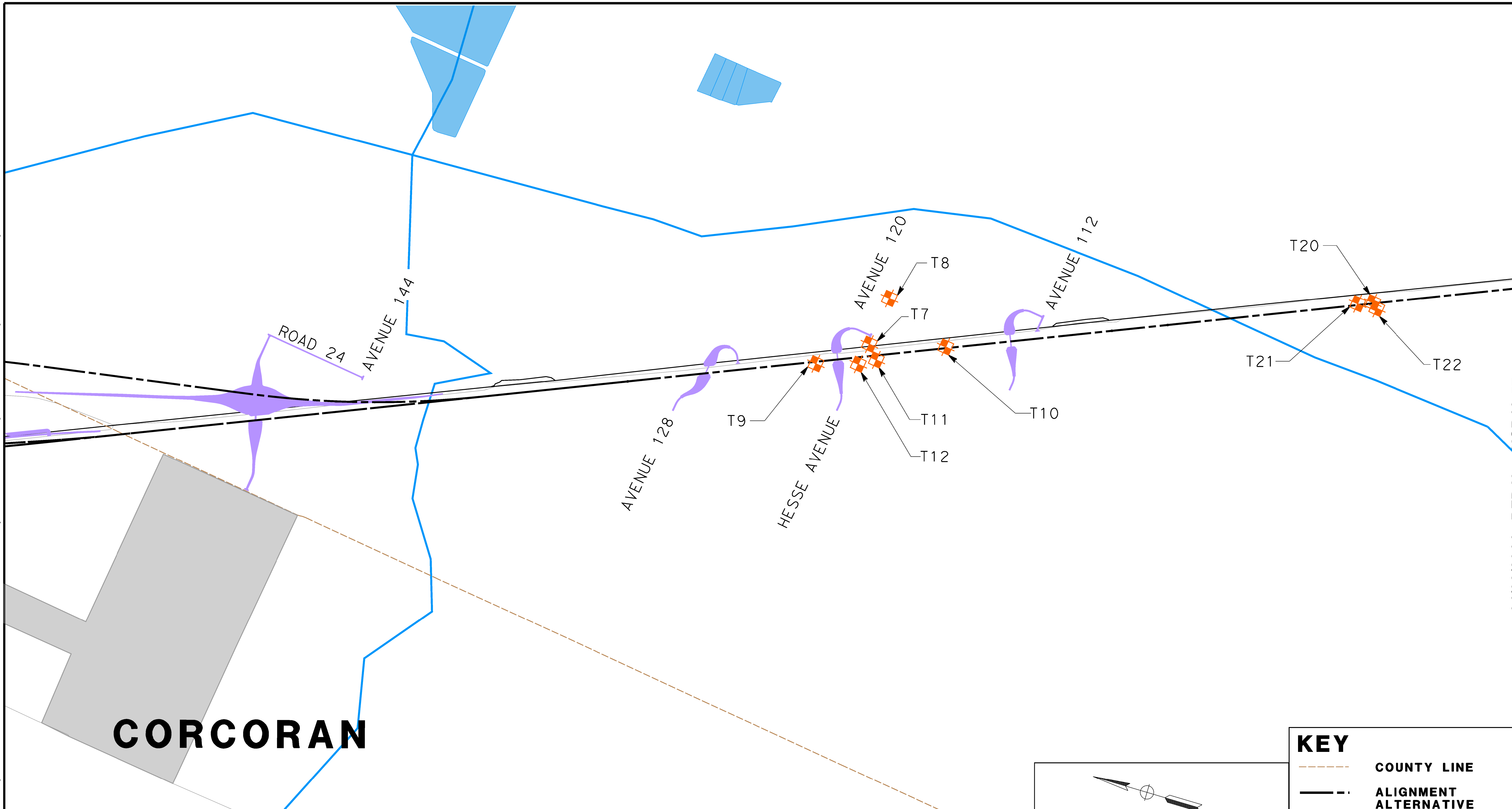


NOTE:

LOCATIONS SELECTED BASED ON THE RATIONALE EXPLAINED IN THE EIR/EIS. LOGS AND PHOTOS PROVIDED ON FIGURES C2 THROUGH C19.

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

CALIFORNIA
HIGH-SPEED RAIL AUTHORITY

CALIFORNIA HIGH-SPEED TRAIN PROJECT
FRESNO TO BAKERSFIELD
ARCHAEOLOGICAL TEST PIT
LOCATION PLAN

FIGURE NO.	C1
DATE	DECEMBER 2013
SHEET NO.	1 of 1

Test Pit Log

Test Pit No. T7
Sheet 1 of 1

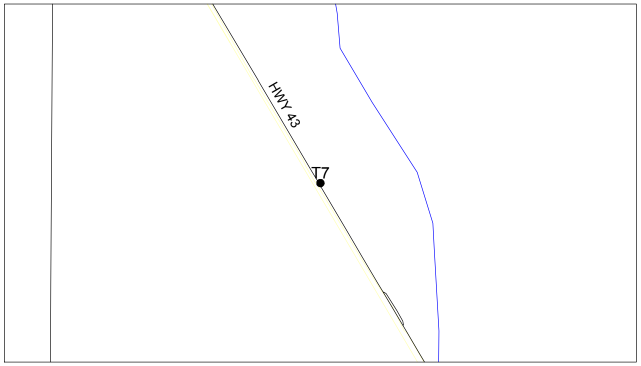
Project Name: California High-Speed Train-FB	Location: Off Ave 120 (East of Hwy 43)
Client: California High-Speed Rail Authority	Project Number: 131577-00
Contractor: Technicon	Operator: Ron Jones
Method/Equipment: JCB 214 Backhoe	JV Field Rep: Brandon Kluzniak
Date/Time Started: 03/04/11 10:20 AM Date/Time Finished: 03/09/11 11:35 AM	Date Backfilled: 03/09/11
	Weather: Mostly sunny, mid 60s (°F)
	Site Conditions: Relatively level, agricultural field; densely covered in grass

Groundwater Level Data

Date/Time	Elapsed Time	Inflow	Groundwater Depth (ft)
			Not Encountered

Site Location

Coordinates: N 1,886,064 ft / E 6,417,040 ft
Elevation: Not Surveyed
Pit Length: 22 ft / Pit Width: 3 ft



Depth (ft)	Type	No.	Field Testing Type/Results (tsf)	Soil Class	Description	Remarks
0				SM	Dry, olive, gray, fine SILTY SAND (SM) little Silt, weakly cemented, frequent rootlets, trace subrounded to rounded fine Gravel.	Soils were classified in accordance with the standards shown on Figures C20a and C20b.
	BAG	1		SP	Dry, light olive & gray, fine, POORLY GRADED SAND (SP), trace Silt, trace fine Gravel.	
5					5.0', Grades with orangish-brown mottling.	
	BAG	2		SP	Dry, light olive gray, fine, POORLY GRADED SAND (SP), no cementation, no fines.	
10				SM	Dry, olive gray, fine, SILTY SAND (SM), little Silt, weakly cemented, with dark reddish brown oxidation staining.	
				SP	Dry, olive gray, fine, POORLY GRADED SAND (SP), trace Silt.	
15					Bottom of T7 at 14.0 feet.	

Sketch of Test Pit Face (Specify Direction)

Figure C2

CALIFORNIA
High-Speed Rail Authority

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

California High Speed Train Project
Fresno to Bakersfield
Test Pit Photo: Test Pit No. T7 – South Wall
03/09/2011 – Figure C3

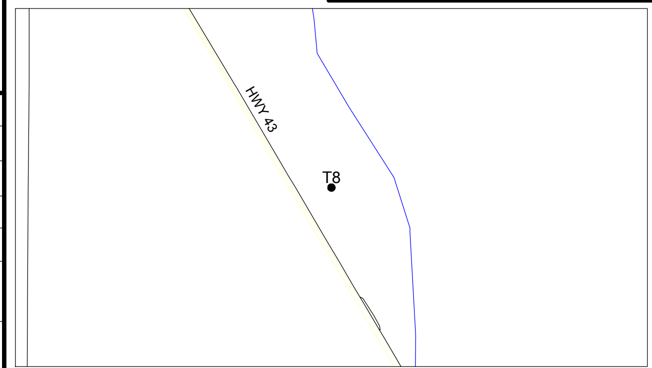
Test Pit Log

Test Pit No. T8
Sheet 1 of 1

URS | HMM | ARUP — California High-Speed Train
CALIFORNIA High-Speed Rail Authority

Site Location

Coordinates: N 1,886,089 ft / E 6,418,819 ft
Elevation: Not Surveyed
Pit Length: 22 ft / Pit Width: 3 ft



Project Name: California High-Speed Train-FB	Location: Off Ave 120 (East of Hwy 43)
Client: California High-Speed Rail Authority	Project Number: 131577-00
Contractor: Technicon	Operator: Ron Jones
Method/Equipment: JCB 214 Backhoe	JV Field Rep: Brandon Kluzniak
Date/Time Started: 03/09/11 12:55 PM Date/Time Finished: 03/09/11 02:00 PM	Date Backfilled: 03/09/11
	Weather: Mostly sunny, ~70 (°F)
	Site Conditions: Relatively level, agricultural field; densely covered in grass

Groundwater Level Data

Date/Time	Elapsed Time	Inflow	Groundwater Depth (ft)
			Not Encountered

Depth (ft)	Type	No.	Field Testing Type/Results (tsf)	Soil Class	Description	Remarks
0					Dry, olive gray, fine, SILTY SAND (SM), trace fine Gravel, frequent rootlets.	Soils were classified in accordance with the standards shown on Figures C20a and C20b.
					Dry, light olive gray, fine POORLY GRADED SAND (SP), trace Silt, trace fine Gravel. 2' to 5', Moderately cemented zones with increased fine Gravel content.	
5						
					Dry, light olive gray, fine POORLY GRADED SAND (SP), no fines, trace medium Sand. 9.5', Strongly cemented pieces (3" diameter, 1.5' long encountered), some carbonate noted.	
10					Dry, dark grayish brown, fine, POORLY GRADED SAND with SILT (SP-SM).	
					Bottom of T8 at 13.5 feet.	
15						

Sketch of Test Pit Face (Specify Direction)

Figure C4

US TEST PIT LOG 131577_CHSTP_TEST PITS.GPJ 131577_CHSTP LIBRARY.GLB 5/26/11

04/02/2014 - RFP No.: HSR13-57

CALIFORNIA
High-Speed Rail Authority

URS | HMM | ARUP
CALIFORNIA HIGH-SPEED TRAIN

California High Speed Train Project
Fresno to Bakersfield
Test Pit Photo: Test Pit No. T8 – South Wall
03/09/2011 – Figure C5

04/02/2014 - RFP No.: HSR13-57

Test Pit Log

URS | HMM | ARUP — CALIFORNIA High-Speed Rail Authority

Test Pit No. T9
Sheet 1 of 1

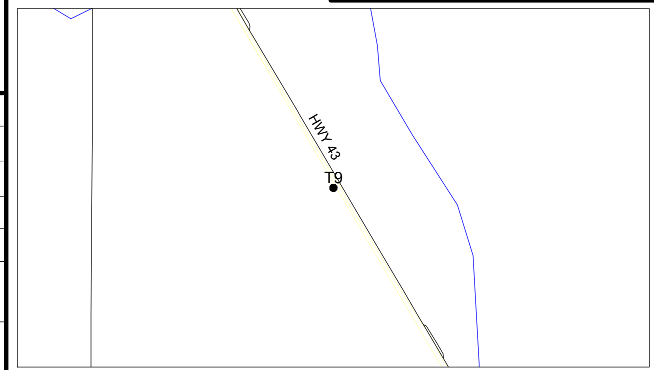
Project Name: California High-Speed Train-FB	Location: Road 36 (South of Corcoran)
Client: California High-Speed Rail Authority	Project Number: 131577-00
Contractor: Technicon	Operator: Ron Jones
Method/Equipment: JCB 214 Backhoe	JV Field Rep: Brandon Kluzniak
Date/Time Started: 03/08/11 10:10 AM Date/Time Finished: 03/08/11 11:30 AM	Date Backfilled: 03/08/11
	Weather: Partly cloudy, mid 60s (°F)
	Site Conditions: Stripped agricultural field; no vegetation, dry

Groundwater Level Data

Date/Time	Elapsed Time	Inflow	Groundwater Depth (ft)
			Not Encountered

Site Location

Coordinates: N 1,887,505 ft / E 6,415,622 ft
Elevation: Not Surveyed
Pit Length: 22 ft / Pit Width: 3 ft



Depth (ft)	Type	No.	Field Testing Type/Results (tsf)	Soil Class	Description	Remarks
0				SM	Dry, olive gray, fine, SILTY SAND (SM), little Silt, weakly cemented, trace medium Sand, frequent rootlets, Sand is micaceous with occasional dark reddish brown stains.	Soils were classified in accordance with the standards shown on Figures C20a and C20b.
	BULK	1				
5					4.5', Grades moist.	
					6.0', Grades with dark reddish brown mottling.	
					7.0', Grades olive gray with occasional decayed vegetation, trace medium Sand.	
10						
				SP	Moist, olive gray, fine, POORLY GRADED SAND (SP), few Silt, Sand is micaceous.	
	BULK	2				
					Bottom of T9 at 14.0 feet.	
15						

Sketch of Test Pit Face (Specify Direction)

Figure C6

US TEST PIT LOG 131577_CHSTP_TEST PITS.GPJ 131577_CHSTP LIBRARY.GLB 5/26/11

04/02/2014 - RFP No.: HSR13-57

CALIFORNIA
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CALIFORNIA HIGH-SPEED TRAIN

California High Speed Train Project
Fresno to Bakersfield
Test Pit Photo: Test Pit No. T9 – East Wall
03/08/2011 – Figure C7

Test Pit Log

Test Pit No. T10
Sheet 1 of 1

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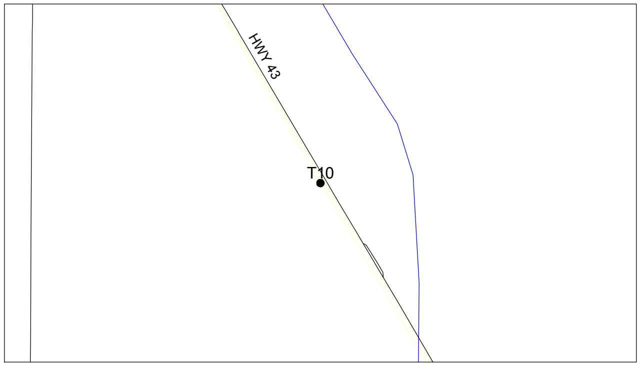
Site Location

Coordinates: N 1,883,545 ft / E 6,418,074 ft
Elevation: Not Surveyed
Pit Length: 21 ft / Pit Width: 3 ft



Project Name: California High-Speed Train-FB	Location: West of Hwy 43 (between Ave 120 and Ave 112)
Client: California High-Speed Rail Authority	Project Number: 131577-00
Contractor: Technicon	Operator: Ron Jones
Method/Equipment: JCB 214 Backhoe	JV Field Rep: Brandon Kluzniak
Date/Time Started: 03/09/11 07:40 AM Date/Time Finished: 03/09/11 09:30 AM	Date Backfilled: 03/09/11
	Weather: Partly cloudy, low 60s (°F)
	Site Conditions: Relatively level, agricultural field; densely covered in vegetation

Groundwater Level Data

Date/Time	Elapsed Time	Inflow	Groundwater Depth (ft)
			Not Encountered

Depth (ft)	Type	No.	Field Testing Type/Results (tsf)	Soil Class	Description	Remarks
0					Dry, olive gray, fine, POORLY GRADED SAND (SP), trace Silt, weakly cemented, frequent rootlets.	Soils were classified in accordance with the standards shown on Figures C20a and C20b.
					Dry, olive gray, fine, POORLY GRADED SAND with SILT (SP-SM), weakly cemented, frequent rootlets, trace shells.	
	BULK	1			Dry, olive gray, fine, POORLY GRADED SAND (SP), weakly cemented, with occasional moderately cemented zones.	
5						
					Dry, olive brown, fine, SILTY SAND (SM), little Silt, trace Clay.	
					Dry, pale olive, fine, POORLY GRADED SAND (SP).	
					Dry, olive gray, fine, POORLY GRADED SAND (SP), trace Silt, Sand is micaceous.	
10					Dry, olive gray, fine, SILTY SAND (SM), little Silt, Sand is micaceous, trace Clay.	
					Medium stiff, dry, olive gray, SANDY LEAN CLAY (CL), some fine Sand.	
	BULK	2	PP = 1.0, 1.0, 1.0 TV = 0.2, 0.15, 0.25			
					Bottom of T10 at 13.5 feet.	
15						

Sketch of Test Pit Face (Specify Direction)

Figure C8

CALIFORNIA
High-Speed Rail Authority

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CALIFORNIA HIGH-SPEED TRAIN

California High Speed Train Project
Fresno to Bakersfield
Test Pit Photo: Test Pit No. T10 – East Wall
03/08/2011 – Figure C9

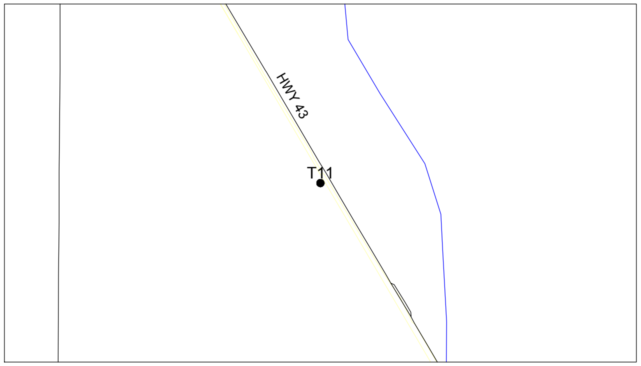
Test Pit Log

URS | HMM | ARUP — CALIFORNIA High-Speed Rail Authority

Test Pit No. T11
Sheet 1 of 1

Site Location

Coordinates: N 1,885,607 ft / E 6,416,632 ft
Elevation: Not Surveyed
Pit Length: 21 ft / Pit Width: 3 ft



Project Name: California High-Speed Train-FB	Location: Just South of Ave 120 (South of Corcoran)
Client: California High-Speed Rail Authority	Project Number: 131577-00
Contractor: Technicon	Operator: Ron Jones
Method/Equipment: JCB 214 Backhoe	JV Field Rep: Brandon Kluzniak
Date/Time Started: 03/08/11 12:50 PM Date/Time Finished: 03/08/11 02:10 PM	Date Backfilled: 03/08/11
	Weather: Partly cloudy, high 70s (°F)
	Site Conditions: Relatively level, agricultural field; densely vegetated

Groundwater Level Data

Date/Time	Elapsed Time	Inflow	Groundwater Depth (ft)
			Not Encountered

Depth (ft)	Type	No.	Field Testing Type/Results (tsf)	Soil Class	Description	Remarks
0					Dry, olive gray, fine POORLY GRADED SAND (SP), trace Silt, weakly cemented, trace fine Gravel, frequent rootlets.	Soils were classified in accordance with the standards shown on Figures C20a and C20b.
	BULK	1			Dry, olive gray, fine, SILTY SAND (SM), little Silt, weakly cemented, occasional decayed vegetation.	
5	BAG	2			Moist, olive gray, fine, POORLY GRADED SAND (SP), no cementation, trace medium Sand. 6.0', Caving on both west and east walls of trench below ~6' depth. 6.5', Grades to light olive gray, with increased medium Sand content.	
10						
					Bottom of T11 at 13.0 feet.	
15						

Sketch of Test Pit Face (Specify Direction)

Figure C10

US TEST PIT LOG 131577_CHSTP_TEST PITS.GPJ 131577_CHSTP LIBRARY.GLB 5/26/11

04/02/2014 - RFP No.: HSR13-57

CALIFORNIA
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CALIFORNIA HIGH-SPEED TRAIN

California High Speed Train Project
Fresno to Bakersfield
Test Pit Photo: Test Pit No. T11 – West Wall
03/08/2011 – Figure C11

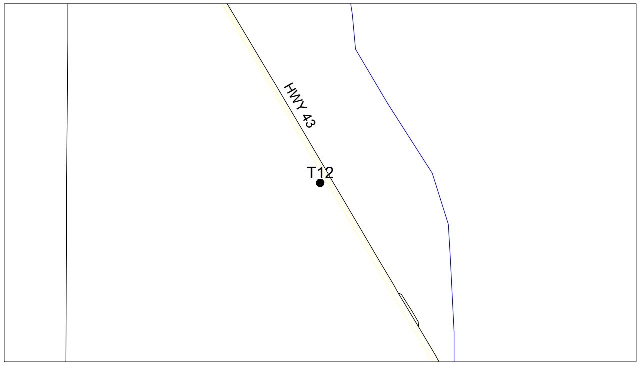
Test Pit Log

Test Pit No. T12
Sheet 1 of 1

URS | HMM | ARUP — CALIFORNIA High-Speed Rail Authority

Site Location

Coordinates: N 1,886,127 ft / E 6,416,228 ft
Elevation: Not Surveyed
Pit Length: 24 ft / Pit Width: 3 ft



Project Name: California High-Speed Train-FB	Location: Road 36 (just South of Ave 120)
Client: California High-Speed Rail Authority	Project Number: 131577-00
Contractor: Technicon	Operator: Ron Jones
Method/Equipment: JCB 214 Backhoe	JV Field Rep: Brandon Kluzniak
Date/Time Started: 03/08/11 07:45 AM Date/Time Finished: 03/08/11 09:30 AM	Date Backfilled: 03/08/11
	Weather: Partly cloudy, low 60s (°F)
	Site Conditions: Relatively level, agricultural field; densely covered in vegetation

Groundwater Level Data

Date/Time	Elapsed Time	Inflow	Groundwater Depth (ft)
8/3/2011 9:00:00 AM			10

Depth (ft)	Type	No.	Field Testing Type/Results (tsf)	Soil Class	Description	Remarks
0					Dry, grayish brown, fine, POORLY GRADED SAND (SP), few Silt, weakly cemented, trace subrounded to rounded fine Gravel, frequent rootlets.	Soils were classified in accordance with the standards shown on Figures C20a and C20b.
	BULK	1				
5						
	BULK	2			8.0', Grades light olive gray, moderate cementation.	
10	BULK	3			Wet, light olive gray, fine to medium, POORLY GRADED SAND (SP), trace Silt, no cementation.	
	BAG	4			Moist, olive gray, SANDY SILT (ML), low plasticity, with alternating layers of dark reddish brown fine Sand.	
					Bottom of T12 at 13.0 feet.	
15						

Sketch of Test Pit Face (Specify Direction)

Figure C12

US TEST PIT LOG 131577_CHSTP_TEST PITS.GPJ 131577_CHSTP LIBRARY.GLB 5/26/11

04/02/2014 - RFP No.: HSR13-57

CALIFORNIA High-Speed Rail Authority

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California High Speed Train Project
Fresno to Bakersfield
Test Pit Photo: Test Pit No. T12 – North Wall
03/08/2011 – Figure C13

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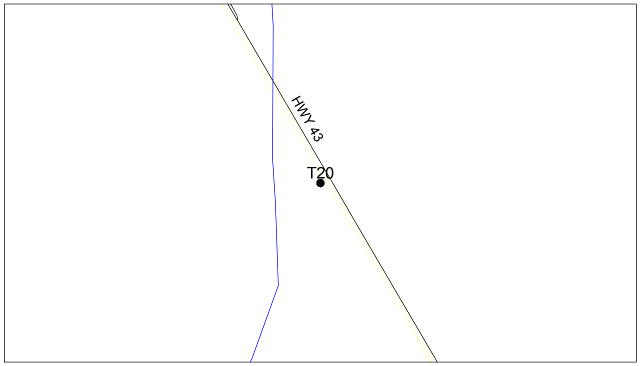
CALIFORNIA High-Speed Rail Authority

Test Pit Log

Test Pit No. T20
Sheet 1 of 1

Site Location

Coordinates: N 1,870,150 ft / E 6,425,668 ft
Elevation: Not Surveyed
Pit Length: 24 ft / Pit Width: 3 ft



Project Name: California High-Speed Train-FB	Location: West of Hwy 43 (near Ave 96)
Client: California High-Speed Rail Authority	Project Number: 131577-00
Contractor: Technicon	Operator: Ron Jones
Method/Equipment: JCB 214 Backhoe	JV Field Rep: Brandon Kluzniak
Date/Time Started: 03/10/11 07:50 AM Date/Time Finished: 03/10/11 09:50 AM	Date Backfilled: 03/10/11
	Weather: Foggy, low 60s (°F)
	Site Conditions: Road shoulder - adjacent to agricultural field; sparsely vegetated

Groundwater Level Data

Date/Time	Elapsed Time	Inflow	Groundwater Depth (ft)
10/3/2011 9:40:00 AM			11.0

Depth (ft)	Type	No.	Field Testing Type/Results (tsf)	Soil Class	Description	Remarks
0					Dry, grayish brown, fine, POORLY GRADED SAND with SILT (SP-SM), Sand is micaceous, frequent rootlets.	Soils were classified in accordance with the standards shown on Figures C20a and C20b.
					Dry, olive gray, fine, POORLY GRADED SAND (SP), trace Silt, Sand is micaceous, trace shell fragments.	
	BAG	1			3.0', Dry, brown, fine SILTY SAND (SM), moderately cemented.	
5	BAG	2	PP = 3.25, 3.75, 3.5 TV = 0.45, 0.45, 0.45		Very stiff, dry, olive gray, SANDY LEAN CLAY (CL), Sand is fine. 6.0', Grades with trace decayed organics.	
					Difficult digging encountered. Very dense, dry, light olive gray, fine to medium, POORLY GRADED SAND (SP), strongly cemented, some carbonate noted.	
10					Moist, olive gray, fine, POORLY GRADED SAND (SP), trace Silt. 11.0', Grades wet.	
					Bottom of T20 at 13.0 feet.	
15						

Sketch of Test Pit Face (Specify Direction)

Figure C14

US TEST PIT LOG 131577_CHSTP_TEST PITS.GPJ 131577_CHSTP LIBRARY.GLB 5/26/11

CALIFORNIA High-Speed Rail Authority

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California High Speed Train Project
Fresno to Bakersfield
Test Pit Photo: Test Pit No. T20 – East Wall
03/10/2011 – Figure C15

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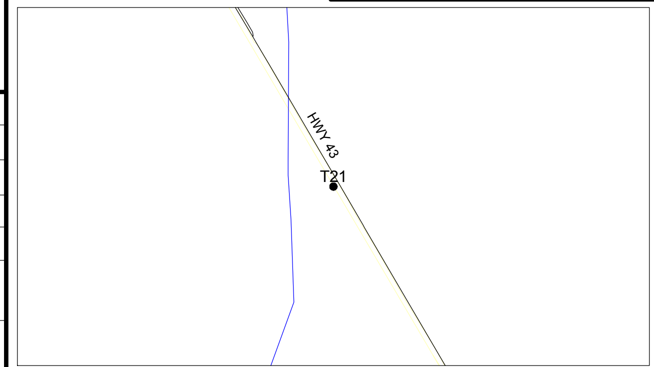
CALIFORNIA High-Speed Rail Authority

Test Pit Log

Test Pit No. T21
Sheet 1 of 1

Site Location

Coordinates: N 1,870,839 ft / E 6,425,538 ft
Elevation: Not Surveyed
Pit Length: 23 ft / Pit Width: 3 ft



Project Name: California High-Speed Train-FB	Location: West of Hwy 43 (near Ave 96)
Client: California High-Speed Rail Authority	Project Number: 131577-00
Contractor: Technicon	Operator: Ron Jones
Method/Equipment: JCB 214 Backhoe	JV Field Rep: Brandon Kluzniak
Date/Time Started: 03/10/11 10:45 AM Date/Time Finished: 03/10/11 12:30 PM	Date Backfilled: 03/10/11
	Weather: Mostly sunny, mid 60s (°F)
	Site Conditions: Road shoulder adjacent to agricultural field; sparsely vegetated

Groundwater Level Data

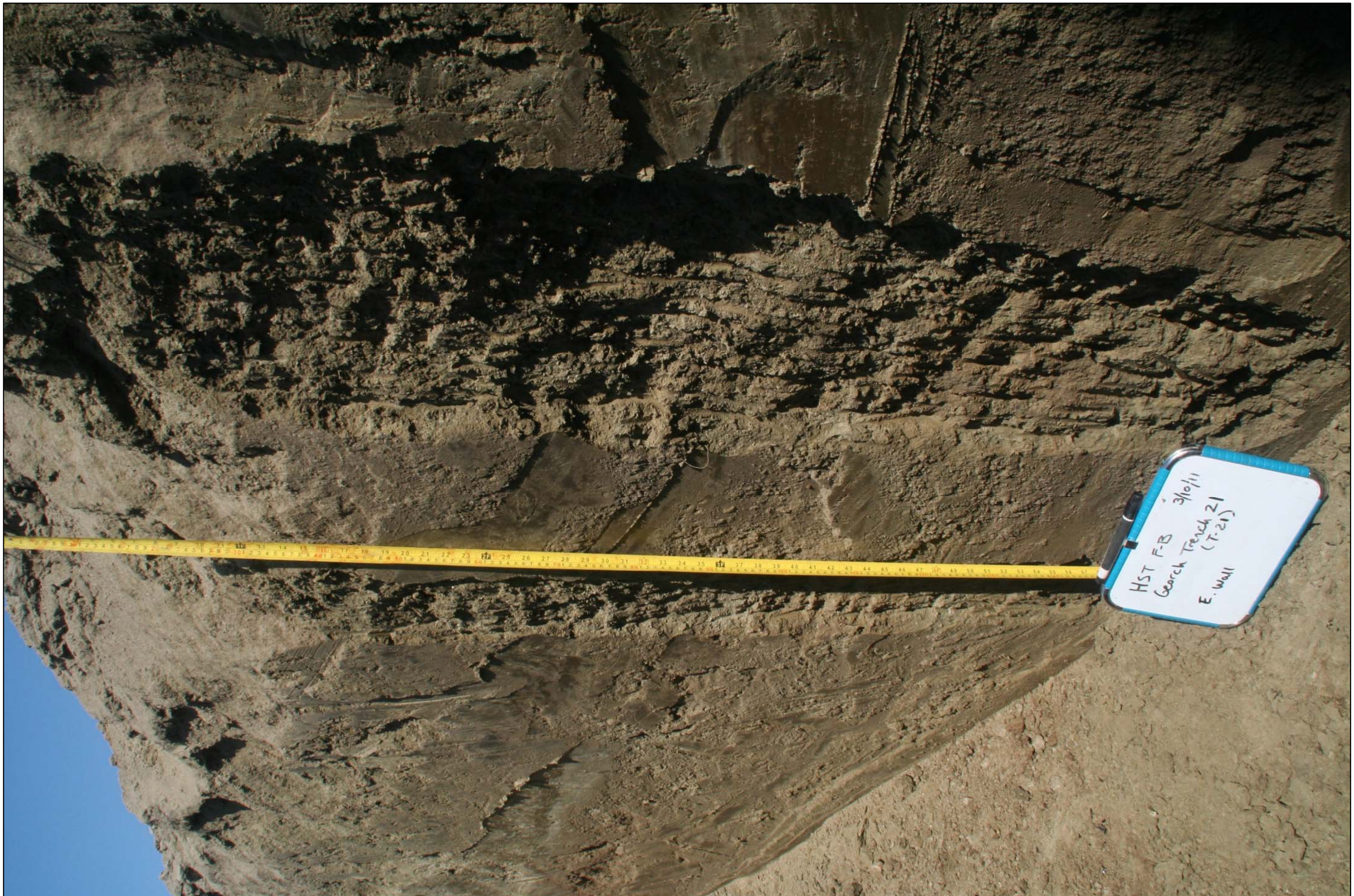
Date/Time	Elapsed Time	Inflow	Groundwater Depth (ft)
10/3/2011 12:20:00 PM			10.5

Depth (ft)	Type	No.	Field Testing Type/Results (tsf)	Soil Class	Description	Remarks
0					Dry, olive gray, fine, POORLY GRADED SAND (SP), trace Silt, slightly cemented.	Soils were classified in accordance with the standards shown on Figures C20a and C20b.
					Dry, olive gray, fine, POORLY GRADED SAND (SP), trace Silt.	
					2.5', Encountered fragments of tar/tar paper.	
					Dry, olive green, fine, POORLY GRADED SAND (SP), trace Silt.	
5					Very stiff, moist, olive gray, SANDY LEAN CLAY (CL), low plasticity.	
			PP = 4.0, 4.25, 4.5 TV = 0.55, 0.55, 0.45			
	BULK	1			Dry, olive gray, fine, POORLY GRADED SAND with Silt (SP-SM).	
					9.0', Grades moist.	
10					Wet, olive gray, coarse to fine, POORLY GRADED SAND (SP).	
	BAG	2			Wet, olive gray, fine, SILTY SAND (SM), some Silt, Sand is micaceous.	
					Bottom of T21 at 14.0 feet.	
15						

Sketch of Test Pit Face (Specify Direction)

Figure C16

04/02/2014 - RFP No.: HSR13-57



California High Speed Train Project
Fresno to Bakersfield
Test Pit Photo: Test Pit No. T21 – East Wall
03/10/2011 – Figure C17

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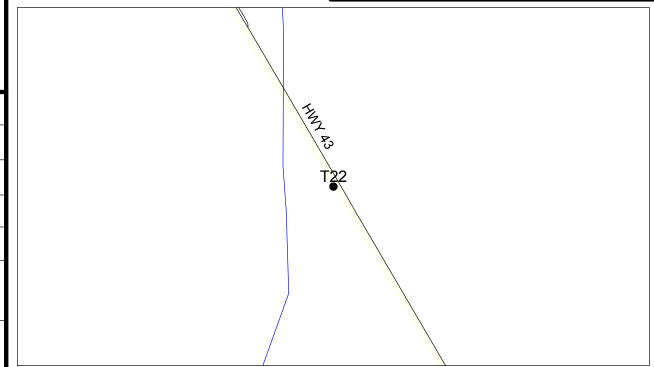
CALIFORNIA High-Speed Rail Authority

Test Pit Log

Test Pit No. T22
Sheet 1 of 1

Site Location

Coordinates: N 1,870,364 ft / E 6,425,795 ft
Elevation: Not Surveyed
Pit Length: 21 ft / Pit Width: 3 ft



Project Name: California High-Speed Train-FB	Location: West of Hwy 43 (off Ave 88)
Client: California High-Speed Rail Authority	Project Number: 131577-00
Contractor: Technicon	Operator: Ron Jones
Method/Equipment: JCB 214 Backhoe	JV Field Rep: Brandon Kluzniak
Date/Time Started: 03/10/11 01:35 PM Date/Time Finished: 03/10/11 03:20 PM	Date Backfilled: 03/10/11
	Weather: Mostly sunny, ~70 (°F)
	Site Conditions: Relatively level, agricultural field; sparsely vegetated

Groundwater Level Data

Date/Time	Elapsed Time	Inflow	Groundwater Depth (ft)
			Not Encountered

Depth (ft)	Type	No.	Field Testing Type/Results (tsf)	Soil Class	Description	Remarks
0					Dry, brown, POORLY GRADED SAND (SP), trace Silt, frequent rootlets.	Soils were classified in accordance with the standards shown on Figures C20a and C20b.
					Dry, olive gray, fine, POORLY GRADED SAND (SP), trace Silt, trace medium Sand.	
	BAG	1			Hard, olive gray, LEAN CLAY (CL), brittle.	
	BAG	2	PP = 2.5, 2.5, 2.5 TV = 0.45, 0.45, 0.40		Medium stiff, moist, olive gray, SANDY LEAN CLAY (CL), low plasticity. 3.5', Grades increasingly sandy with depth.	
5					Moist, olive gray, fine, POORLY GRADED SAND (SP), trace Silt.	
	BAG	3			Hard, moist, dark olive, SANDY LEAN CLAY (CL), trace dark reddish brown organics.	
					Bottom of T22 at 7.5 feet.	
10						
15						

Sketch of Test Pit Face (Specify Direction)

Figure C18

CALIFORNIA High-Speed Rail Authority

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California High Speed Train Project
Fresno to Bakersfield
Test Pit Photo: Test Pit No. T22 – West Wall
03/10/2011 – Figure C19